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PROGRAM MANAGER
RMA CONTAMINATION CLEANUP

U.S. ARMY
MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

FINAL
REPORT
SEPTEMBER 1988
TASK NO. 27
VOLUME I - REPORT

HAZARDOUS WASTE LAND DISPOSAL FACILITY ASSESSMENT

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HAZARDOUS WASTE LAND DISPOSAL FACILITY ASSESSMENT
CONTRACT NO. DAAK11-84-D-0017

Prepared by:

EBASCO SERVICES INCORPORATED
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Prepared for:

U.S. ARMY PROGRAM MANAGER'S OFFICE FOR
ROCKY MOUNTAIN ARSENAL CONTAMINATION CLEANUP

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1.0 SUMMARY

1.1 PURPOSE

The overall objective of this task is to perform an assessment of a land disposal facility capable of containing all Rocky Mountain Arsenal (RMA) waste. This task is intended to fit into the framework of Federal and state regulations for hazardous waste site remediation under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements. It fits into the RMA feasibility study program as one of the technologies to be screened for their technical applicability to the site. This task helps build the overall RMA cleanup strategy for the onsite containment alternatives required to be evaluated under the CERCLA feasibility study process.

1.2 SCOPE

To accomplish the overall task objective the following activities have been performed:

- Review available literature and documents, including the most current data available in the remedial investigation (RI), to define and characterize the volumes and types of wastes requiring remediation;

- Select the most suitable site(s) available on RMA based upon the optimum combination of geologic, geographic, health, environmental, and economic considerations consistent with the requirements of the National Contingency Plan (NCP);

- Select design criteria to be used for the assessment;

- Review literature to consider the technology available for waste cells, to evaluate various waste cell concepts, and to select the optimum concept;

- Evaluate various land disposal facility layouts and select the layouts best suited to each specific disposal site;

- Prepare an assessment to provide a basis for construction schedules and cost estimates;

- Develop a preliminary schedule and cost estimate for the construction of the facility;

- Develop guidelines for waste cell construction specifications, and quality assurance procedures;

- Prepare a report describing the waste sources, site selection rationale, facility and waste cell concept configurations, estimated construction quantities and costs, guideline construction specifications and quality control procedures.

1.3 CONCLUSIONS

Work performed under this task supports the following conclusions:

- It appears that a hazardous waste land disposal facility with sufficient capacity to accept all currently estimated volumes of waste, and which will meet the substantive requirements of the identified state and federal regulations governing such facilities, can be designed and sited at RMA.

- Information developed in the ongoing remedial investigations of contaminated sites at RMA indicates that a facility capable of accepting 16 million cubic yards of waste is adequate to contain all RMA waste, including treatment residues from processes required to reduce the concentration, toxicity, or mobility of restricted wastes.

  These volume estimates are sensitive to action levels, which have not been established. In this task, detection limits for organics and natural background concentrations for metals were used as the basis for estimating volumes of contaminated materials.

- Not all RMA wastes can be disposed at such a facility. No liquid wastes or PCBs can be disposed, for example. The facility is able to accept solidified liquid wastes, for which volume estimate has been made.

- The predominant waste form by volume at RMA is contaminated dry soil, which is a favorable material for land disposal since it does not present settlement or leachate generation problems.

- The semiarid climate of RMA is favorable for successful land disposal since little or no deep percolation of rainfall occurs in vegetated areas.

- The best sites on RMA for such a facility are the area between Basin F and the North Plants, and an area near the eastern boundary of RMA.

- A facility consisting of a few large waste cells is significantly more economical than one with a larger number of smaller cells.

- The total cost of a facility to contain all RMA waste ranges from about 150 to 250 million dollars depending on cell size and buildout period.

1.4 RECOMMENDATIONS

Site specific geohydrological and geotechnical information will be required if it is desired to advance the concept assessment, which was based on general RMA data, to the design stage. Some values of soil properties which were used in the demonstration of facility protective life were regional values and also need to be confirmed for specific sites before detailed design begins.

Because of the high level of confidence in the technology which will be required before it is incorporated into the final selection of alternates (Record of Decision, or ROD), the properties of the soil column under the

facility site should be investigated to the extent necessary to confirm the facility protective life prior to the issuance of the ROD. A description of the recommended field and laboratory investigations to obtain the required information is provided as Appendix V.

A sufficient quantity of suitable clay may not be available on the Arsenal. Field tests to determine the effectiveness and cost of modification of RMA soils to create manufactured clay for waste cell liners should be performed to confirm the general information on which the concept development and cost estimates are based.

Finally, the construction procedures described in the operations plan should be confirmed based on field experience in construction of test fills or complete waste cells. Test cells may be scaled down or prototype size as desired.

2.0 INTRODUCTION

The overall objective of this task is to perform an assessment of a land disposal facility capable of containing all RMA waste.

The specific objectives are to:

- Characterize the various wastes requiring land disposal;
- Select the most suitable site for a land disposal facility on RMA;
- Prepare a conceptualization of a land disposal facility with enough detail for a feasibility-level estimate of schedule and cost; and
- Estimate schedules and costs for construction and post-construction monitoring.

This task is developed to fit into the framework of federal and state regulations for hazardous waste site remediation under CERCLA requirements. This task helps build the overall RMA cleanup strategy for all contaminated sites for the containment options required to be evaluated under the CERCLA feasibility study process. Evaluation of containment options requires the assessment of an on-site land disposal facility concept for contaminated material as part of the overall RMA feasibility study.

Figure 2-1 shows the schematic relationship of the on-site hazardous waste land disposal facility to the overall RMA cleanup. It can be seen that the onsite options fall into two categories, identified as the "in situ option" and the "on-site option."

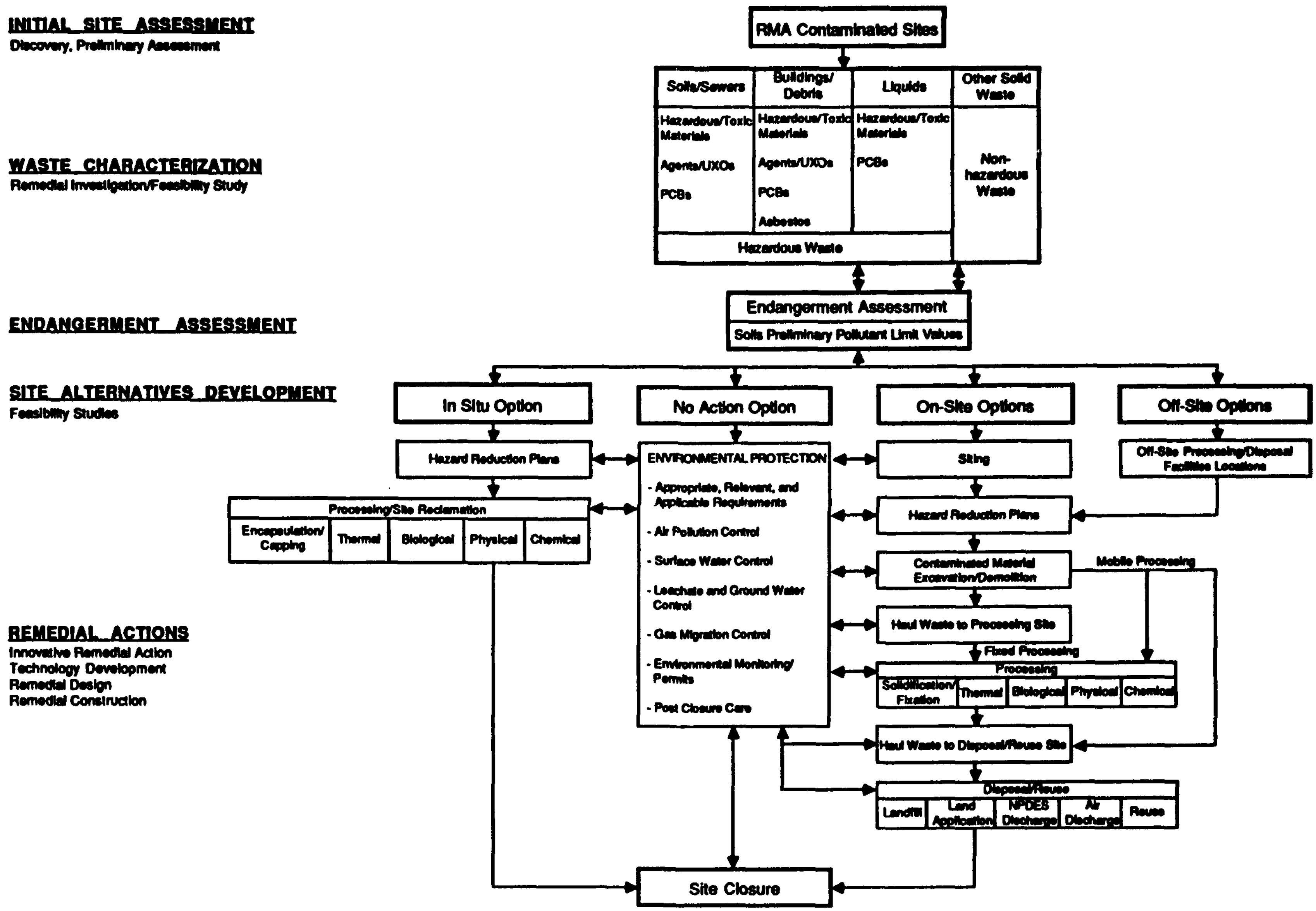


Figure 2-1
Relationship of On-Site Land Disposal Facility to Overall RMA Cleanup

Prepared for:
U.S. Army Program Manager's Office
Rocky Mountain Arsenal Contamination Cleanup
Aberdeen Proving Ground, Maryland

This option also covers technologies that extract contaminated materials and treat and replace them without general ground disturbance. The on-site option involves recovery of contaminated materials for processing, followed by disposal of the solid fraction of processing residues by either land application or landfill.

This report develops the basis for assessing the cost-effectiveness of those remedial action alternatives that include land disposal facilities. It incorporates and draws upon the most current information available regarding the regulatory setting, the state-of-the-art in technology, and the characteristics of RMA itself, both as a contaminated site to be remediated and as an area in which to locate candidate sites for a land disposal facility.

The information drawn upon is sufficient to support the development of a concept that can be demonstrated to be protective in accordance with the regulations, based on reasonable extrapolations and assumptions regarding available information. For example, the facility sites chosen are located in areas of RMA that have not been subject to intensive investigation. Therefore, information gathered elsewhere on RMA where more investigations have been performed are assumed to apply to the candidate facility sites as well.

If the landfill concept is pursued further in the remedial action process, it is recommended that detailed investigations be performed for specific sites in support of further facility design development. Recommendations for gathering the necessary information are also included in this report.

3.0 SITE SELECTION

3.1 OBJECTIVES AND BACKGROUND

The objectives of the site selection process are to locate and recommend the best possible site(s) on the Arsenal for on-site disposal of up to 16 million compacted cubic yards (ccy) of contaminated soil, building debris, and treatment residues (Appendix I.3, Table I-2). Consequently, this site selection process does not consider off-site locations nor any sites that may cross the Arsenal boundary.

The purpose of site selection was to provide site characteristic information necessary for facility layout and for economic evaluations of different design options. Characteristics such as site size, topography, and distance from the waste sources were developed to support the subsequent phases of the task. Although the site selection phase preceded the other phases of this task, engineering requirements and post-closure considerations were included in the development of site selection criteria.

Existing data were used in the site selection database. Field studies to further characterize and refine the location of the site(s) described in this report are recommended and discussed in Volume II, Appendix V, but are beyond the scope of this study.

The results of two previous studies provide background information for the site selection process.

The first study used as a basis for the site selection was a 1983 U.S. Army Engineer Waterways Experiment Station (WES) site suitability study for land disposal of Basin F material (Crabtree & Thompson, 1983). That study included a formal site selection process that developed geotechnical selection criteria, recommended a site, and conducted

field studies to determine the hydrogeologic character of the selected site. It did not include a thorough review of regulatory requirements for development of site selection criteria. The study identified a disposal site that was large enough only for Basin F material, about 40 acres. The study did, however, provide guidance for developing a formal site selection process and comprehensively considered the entire Arsenal in the site screening procedure. The WES study was used in this report for criteria development and as a basis for site selection methods as discussed in Section 3.4.

The second study, the "Decontamination Assessment for Land and Facilities (DALF) at RMA" (USATHAMA, 1984) provided the basis for the volume estimates for siting a disposal facility as discussed in Appendix I.3. The DALF also addressed on-site disposal options in addition to other technologies. This study supported the on-site disposal option by stating that a facility can be designed to operate properly, even though the Colorado Geological Survey's recommended conditions (Hynes & Sutton, 1980) of thick impermeable bedrock do not exist at RMA. The DALF, drawing on the conclusions of the earlier WES 1983 report, recommended a site in the northeast quarter of Section 36 on RMA as complying with the EPA siting criteria.

3.2 GENERAL RMA CHARACTERISTICS

Before developing site selection criteria, it is important to review the general site characteristics of RMA to better understand the significance of these criteria and their implications for selection of a specific site(s). The general characteristics of the Arsenal-wide geology, topography, climate, surface hydrology, and subsurface hydrogeology are described below to provide a context from which a site(s) will be recommended for a land disposal facility. The site-specific characteristics of recommended sites will be discussed in Section 3.8.

Geology

The relatively young unconsolidated stratigraphic units (Pleistocene and recent ages) at RMA consist of alluvium with a thin veneer of aeolian deposits on the topographic highs, overlying the older and largely consolidated Denver Formation. Alluvial and aeolian soils cover the entire Arsenal except in small areas, generally on topographic highs, where the underlying Denver Formation is exposed. The thickness of the alluvium ranges from zero to at least 127 feet, with the thickest alluvial deposits being found within buried bedrock surface channels found across RMA. The alluvium consists of clays, silts, sands, gravels, and boulders and is generally unconsolidated except in localized areas of calcium carbonate cemented conglomerates. Large boulders, composed of igneous rock, chert, quartz, and petrified wood, cap the topographic highs and lie in some of the deep channels. The sands are lenticular in certain areas and grade laterally into clays, silts, and gravels.

The Denver Formation within RMA has a maximum inferred thickness of 400 to 600 feet based on regional estimates. The Denver Formation consists primarily of clay shale and lenticular bodies of compact sand with thin zones of silt, clay, lignite, coal, siltstone, and sandstone, some of which are volcaniclastic. The structure of the hard bentonitic clay shale ranges from blocky to laminate and fissile. The clay shale units can be 10 to 30 feet thick, but commonly are interbedded with thin zones of fine sand, sandstone, or siltstone. Many of the clay shales originated as delta plain deposits rich in volcanic ash (Crabtree & Thompson, 1983). These geologic characteristics were considered in developing criteria for use in screening potential sites and in developing siting alternatives.

Climate, Topography, and Surface Hydrology

The Arsenal consists of a nearly treeless plain over most of its area. The climate is that of the semi-arid high plains, and periods of drought one to two years in length are fairly common. Precipitation averages

15 inches annually, with two years in ten experiencing less than 9 inches and two years in ten more than 18 inches. Runoff is intermittent and only follows heavy precipitation or snowmelt. Most of the yearly precipitation occurs between March and August.

The agricultural growing season is defined as the 150 days between last frost and first frost; however, soil temperatures are high enough to sustain plant growth for about 250 days of most years. From mid-June until early November, the near-surface soil moisture is depleted below the wilting point by evaporation and transpiration losses; the rest of the year the soils store any excess moisture. In average years, less than 3 inches of available moisture is stored at any time in a soil that has native grass vegetation; therefore, free soil moisture does not normally penetrate much below 12 inches in medium textured or moderately fine textured soils, as borne out by observations of visible calcium deposit horizons at depths of from 7 to 20 inches in Adams County soils of the types found at RMA (Sampson & Baber, 1974).

The two major watersheds that contribute intermittent runoff from outside the Arsenal boundary are First Creek, a well-defined channel crossing RMA, and Irondale Gulch, which has a poorly defined channel due to drainage area modification and carries water across RMA only during major storms; otherwise, the runoff feeds a series of small lakes having no normal surface outlet. Both watersheds follow the prevailing slope to the northwest (Resource Consultants, 1982).

These surface hydrologic features were considered in developing criteria for use in screening potential sites and in developing siting alternatives.

Hydrogeology

RMA lies within the Western Mountain Ranges Groundwater Region, as defined by Heath (1982). This region is characterized by narrow alluvial valleys and mountains with a minor alluvial aquifer underlain by confined rock aquifers. Recharge is derived primarily from precipitation over upland areas and along stream channels, and discharge is primarily to springs and seeps (May et al., 1983). The low hydraulic conductivity of the rock aquifers results in generally low well yields of less than 100 gallons per minute (gpm), but the alluvial aquifer can, in places, produce appreciable flow rates (Crabtree & Thompson, 1983). The alluvial aquifer found beneath RMA is used off-site as the major drinking water supply for the residents in the immediate vicinity of RMA, with production wells pumping as much as 1,000 to 2,000 gallons/minute (Gearhart, 1987).

In general, the alluvial water table throughout most of RMA is controlled by a fairly constant artesian pressure head from the Denver Formation (May et al., 1983). The major features that produce significant localized, periodic, or continual fluctuations in the water table are the South Plants mound, the South Plants lakes, and First Creek (Crabtree & Thompson, 1983). The general depth from ground surface to groundwater table varies from near-surface in the South Plants area to 65 feet or more in the Western Tier.

Groundwater recharge in the vicinity of the Arsenal is derived from the infiltration of precipitation over the area, if any, and subsurface flow from deep in the Denver Formation. Discharge is to evapotranspiration, streams, well pumpage, and subsurface flow through the Denver Formation. Groundwater flow is primarily to the northwest; however, the water table aquifer, which includes the alluvium and portions of the Denver Formation, exhibits complex local flow directions. Locally, groundwater flow generally coincides with topography, groundwater mounds being found under topographic highs, and depressions in the water table along streams and in the vicinity of pumping wells (Crabtree and Thompson 1983).

The largest alluvial groundwater flow moves west and northwest from a point south of the South Plants lakes. There is a smaller flow toward the northern boundary of RMA.

Denver sand units are in contact with the alluvium in many areas. Many of these Denver sand units are thin and lenticular, but some are thick particularly in the area of Basin F and northwest of Basin A. These sands could be contributing to the groundwater flow in the alluvium in these areas (Crabtree & Thompson, 1983).

These hydrogeologic characteristics were considered in developing criteria for use in screening potential sites and in developing siting alternatives.

3.3 REGULATORY REVIEW AND SITING CRITERIA

Cleanup activities at RMA must comply with statutory requirements related to remedial activities at CERCLA sites. In October 1986, the "Superfund Amendments and Reauthorization Act" (SARA) was signed into law. SARA provided significant clarification of CERCLA, especially as it applies to the determination of "Applicable or Relevant and Appropriate Requirements" (ARARs) including both state and Federal requirements. To assure compliance with this CERCLA requirement, a preliminary review of Federal and state statutes was conducted to identify regulations that specifically apply to the siting and design of a land disposal facility at RMA (final ARARs will be included in the Task 28 Feasibility Study). The regulations were used to develop site selection and facility design criteria. Site selection criteria are discussed below, while design criteria are discussed in Section 4.

The seven site selection criteria used here are listed in Table 3-1. The first four criteria are based on state regulations while the remaining three criteria are derived from either previous studies or assumptions used in the facility design (Section 5). The regulations cited in Table 3-1 are the Colorado Hazardous Waste Facility Standards from the Code of Colorado Regulations (CCR). These state regulations

TABLE 3-1

INITIAL SITE SELECTION CRITERIA AND
THE APPLICABLE REGULATION OR REFERENCE

Criterion	Regulation or Reference
1. Located more than 1,000 feet from a fault that has had displacement in Holocene time (Mandatory)	CCR* Title 6, Ch. 1007, Article 3, Subpart B, 264.18(a)
2. Located outside the 100-year Floodplain (Mandatory)	CCR Title 6, Ch. 1007, Article 3, Subpart B, 264.18(b)
3. Maximize depth to groundwater (40 feet initial target)	None
4. Minimum distance to Arsenal boundary - 1,000 feet	Colorado Noise Abatement Statute Sections 25-12-101 to 25-12-108
5. No saturated alluvium underlying the site	Crabtree and Thompson, WES, 1983
6. Not coincident with avoidance areas including highly contaminated areas and dedicated land uses	USATHAMA 1984
7. Maximize area (1,000 acres initial target)	Appendix I, Waste Characterization; IT, 1984

* Code of Colorado Regulations.

supersede the Federal regulations where they are equivalent to or more stringent than the Federal regulations as required by Section 121 of SARA. Equivalent Federal regulations can be found in 40 CFR Part 264 which is the codification of the Resource Conservation and Recovery Act (RCRA).

The seven criteria in Table 3-1 are discussed below with their justification and utility to the site selection process. The application of these criteria to the site selection process is discussed in Section 3.4.

Seismicity Criterion

The first site selection criterion, that a site be not less than 1,000 feet from a fault active in Holocene time, is a mandatory site selection criterion that is in substantial compliance with CCR 1007-3, Section 264.18(a) as cited in Table 3-1. A similar Federal regulation calls for a seismic location standard of 200 feet from a Holocene fault (40 CFR Section 264.18(a)). The more stringent 1,000 foot state criterion, however, is adopted herein in accordance with the provisions of CERCLA Section 121(d)(2), 42 USC Section 9621(d)(2). The purpose of a mandatory seismic location standard is to isolate land disposal facilities from areas where seismic activity may result in rupture of the ground surface. Faults were not mapped as site selection criteria because accurate maps were not available. However, an in-depth review of seismic activity at RMA was conducted in order to address the site selection regulations.

Review of historical seismicity in Colorado indicates that, while most of the state is relatively aseismic, the Rocky Mountain Arsenal area has experienced moderate levels of seismicity. In 1882 an intensity VII event occurred in the present day Denver metropolitan area (Hadsell, 1967). Intensity data suggest that this earthquake originated north of Denver, near present day Broomfield or Louisville (Costa & Bilodeau, 1982). During the 1960s an extended swarm of earthquake activity occurred in the vicinity of a deep (12,045 foot; Shell, 1987) waste

injection well located near Basin F of the Rocky Mountain Arsenal. The largest events occurred in April and August 1967, and were magnitude 5.1 and 5.3 respectively (Kirkham & Rogers, 1981). Most investigators are of the opinion that stress changes associated with the injection of waste resulted in the release of tectonic stress as earthquakes (Healy et al., 1968; Kirkham & Rogers, 1981; Costa & Bilodeau, 1982).

Detailed studies of this seismicity define its source as a linear zone striking northwest-southeast trending approximately through the disposal well location. Fault plane solutions indicate right-lateral motion along northwest striking planes, consistent with the overall trend of the observed seismicity. Based on the observed northwest-southeast hypocentral distribution, consistent focal mechanism data, and intense fracturing in cores of Precambrian basement rocks taken from the bottom of the injection well, several investigators suggested the existence of a northwest trending fault, which is referred to as the Derby Fault (Kirkham & Rogers, 1981).

Although the level of seismicity along the Derby Fault decreased several years after the injection of wastes was stopped, some low level seismic activity still continues. Further, some investigators (Costa & Bilodeau, 1982; Kirkham & Rogers, 1981) suggest that seismicity along the Derby Fault may have eventually occurred even if the Arsenal well had not been drilled. They point to the intensity VII earthquake of 1882 and events such as the magnitude 4-plus earthquake of April 1981 as evidence of continued tectonic stress accumulation in the Denver area.

As a result, controversy continues as to the seismic hazard that the Derby Fault presents today. Nevertheless, the documented seismicity indicates that this feature has experienced displacement during Holocene times. Further, since Federal regulations make no distinction between induced displacement versus displacement resulting from tectonic activity, the postulated Derby Fault has been considered a locale of Holocene displacement.

The vertical surface projection of the postulated Derby Fault extends through or very near Basin F. However, detailed geological and geophysical surveys conducted during the 1960s suggest that it does not extend into the sedimentary rocks overlying the linear zone of earthquakes (Hollister & Weimer, 1968). Further, the hypocentral distribution of activity suggests that the Derby Fault is restricted to the basement rocks located at least 10,000 feet beneath Basin F (Healy et al., 1966). Consequently, if the Derby Fault exists, it is more than 1,000 vertical feet from any proposed surface facility. Since Federal and state regulations do not distinguish between vertical or horizontal distance, the Derby Fault does not represent a siting restriction.

A series of faults within the Denver Formation beneath Basin A are also identified by May et al., (1983). Basin A is located a few thousand feet to the southeast of Basin F. Based on review of the boring logs and geologic sections presented by May et al., these faults most certainly do not represent Holocene displacements. For example, as noted in the May et al., report, the two northwest trending faults define a northwest trending upthrown fault block (horst). However, Basin A, a topographic and structural low since Pleistocene times, lies over this uplift feature.

The presence of a basin over a horst structure is inconsistent with the sense of displacement along these faults as inferred from May's borings. May suggests that the apparent inconsistency in geometry suggests the following sequence of events: 1) uplift along these faults, resulting in the exposure of sediments within the fault block that were less resistant than the volcanics capping the downthrown sides of the fault; 2) erosion of these less resistant sediments, resulting in the formation of an eroded structural low; and 3) subsequent deposition of the Pleistocene lacustrine and alluvial deposits present in Basin A.

These observations indicate that the Basin A faults are at least early Pleistocene. Consequently, these features do not represent a siting

restriction as defined in the Federal regulations concerning Holocene displacement. Later investigations such as that of Crowder (Crowder et al., 1987) have not altered this finding.

Floodplain Criterion

The second mandatory site selection criterion is that the disposal facility be located outside of the 100-year floodplain. This criterion is in substantial compliance with 6 CCR 1007-3, Section 264.18(b), as cited in Table 3-1 (an equivalent Federal regulation can be found in 40 CFR Section 264.18(b)). The purpose of the 100-year floodplain as a siting criterion is to avoid any significant adverse impacts from flood erosion of the facility and consequent exposure of disposed materials by siting the disposal facility outside the area inundated by the flood.

The Standard Project Floodplain (SPF) was actually used as the siting criterion because a data source was readily available from a previous study (Crabtree & Thompson, 1983). The SPF is calculated from a storm defined as "the combination of severe meteorological events that gives the maximum precipitation reasonably characteristic of the geographic region of interest, excluding extremely rare events" (Ibid). The standard project storm has a frequency that may range between 100 and several thousand years. The 100-year floodplain is calculated from the 100-year storm, which has a 1 percent probability of being equaled or exceeded each year. The SPF portrays a larger inundated area and consequently a more catastrophic event than the 100-year flood. Since the SPF represents a larger potentially inundated area, it is considered more conservative for use in siting than the 100-year floodplain and therefore is an appropriate exclusionary criterion.

Depth-to-Groundwater Criterion

The third site selection criterion is to maximize the depth to groundwater. The depth-to-groundwater criterion is defined as the difference in elevation between the ground surface and the water

table. This definition assumes an at-grade or existing surface level facility. Methods used to calculate the depth to groundwater at RMA are discussed in Section 3.4.

There are no applicable or relevant and appropriate Federal or state standards that provide a specifically delineated depth-to-groundwater criterion.

A 40 foot depth to groundwater was used in the previous disposal siting study at RMA (Crabtree & Thompson, 1983) and is used herein to obtain a calculated travel time for leachate to migrate using the U.S. Environmental Protection Agency (EPA) HELP Model, version 1986 (Schroeder et al. 1984).

Travel time calculations were based on a total facility design including the site performance in combination with the engineered barriers. The 40 foot depth-to-groundwater criterion contributed to the overall facility design criterion to isolate wastes away from pathways that could expose the public to contamination for many years. The 40 foot depth-to-groundwater criterion was shown, in combination with the complete facility design through the use of the HELP model, to ensure approximately 1,000 years of waste isolation. The 40 foot value of the depth-to-groundwater criterion contributes a calculated minimum 726 years. The actual travel time calculations results and assumptions used in the HELP model are included in Section 5.4, Selection of Cell Components.

It is possible, and may be desirable for other reasons, to produce a facility design that is shown to be protective using a smaller depth to groundwater. However, such a design would place greater reliance on the engineered barriers as the geological barrier is reduced. Actually, the presence of the waste cell greatly alters the groundwater flow in the unsaturated soil zone beneath it, so that the value of the depth-to-groundwater criterion depends on the design details of the facility. This is demonstrated in Section 5.4.

Buffer Zone Criterion

A minimum 1,000 foot buffer zone from the edge of the Arsenal is the fourth siting criterion listed in Table 3-1. The pertinent statute does not specify a minimum distance but only requires that noise be controlled to within allowed levels at the nearest point of public exposure. The 1,000 foot distance was derived through an investigation of both potential aesthetic and noise impacts.

The 1,000 foot distance was the minimum required to demonstrate a reasonably small aesthetic impact. A viewer standing 1,000 feet away from the proposed maximum facility height of 60 feet (see Section 6 for design height determination) would observe a 3° obstruction to his/her view. On the southern and western boundaries of the Arsenal there are comparable industrial structures 60 feet or greater in height. This maximum facility height would therefore be considered acceptable when compared to existing structures. A design height of 30 feet would obstruct a correspondingly smaller angle of 1.7° with even less visual obstruction.

The second reason for the 1,000 foot distance is calculated noise impact. Under a worst-case construction scenario (Appendix III), a maximum of four trucks or tractors would be operating simultaneously (one loader, one bulldozer, and two haulers). Based on U.S. General Services Administration (GSA) specifications, tractors and trucks may not exceed 75 dB at a distance of 50 feet. The effect of four vehicles would be 6 dB more for a total noise level of 81 dB at 50 feet. Using the standard formula that a doubling of distance reduces the noise by 6 dB, and assuming the worst case wherein all vehicles are located side by side, a distance of 1,000 feet is required to reduce tractor noise levels from 81 dB to below 55 dB (Fader, 1981). This 55 dB level is a

noise standard at which disturbance is considered negligible (EPA 1982) and meets the most restrictive classification of the state regulations.

Based on these calculations for potential noise and visual impacts, the 1,000 foot buffer distance was considered to be the minimum distance away from the edge of the Arsenal for facility siting.

Unsaturated Alluvium Criterion

The fifth siting criterion is the absence of saturated alluvium underlying the site. "Saturated alluvium" describes a condition where the water table is higher than the bedrock surface. The absence of saturated alluvium theoretically presents a favorable siting condition in that the bedrock forms a barrier or cap over the groundwater, isolating the groundwater from any potential leachate.

The unsaturated alluvium criterion was used in an earlier site selection study at RMA (Crabtree & Thompson, 1983) and was adopted for this task as an additional groundwater protection criterion. The use of unsaturated alluvium as a siting criterion goes beyond Federal and state requirements for groundwater protection since there are no regulations for this criterion. The benefit of satisfying this criterion is dependent on the lithology of the bedrock between the site surface and the groundwater. At RMA, the bedrock in places encloses or partly encloses unconsolidated sand bodies that would not form barriers over groundwater. For that reason this criterion is considered desirable but not mandatory, and credit has not been taken in calculating the groundwater travel time achieved by the facility.

Avoidance Area Criterion

"Avoidance Areas" is the sixth siting criterion listed in Table 3-1. Avoidance areas at RMA include known contaminated areas and areas of dedicated land use. Contaminated sites include Basin F, Basin A, and

South Plants according to the most recent Contamination Assessment Reports (Appendix I). Dedicated land use areas have long-term operational commitments or existing operational uses that would present a hindrance to the development of a waste disposal facility. Dedicated land use areas include the Post Office, Stapleton runway, the three existing groundwater treatment systems, and North Plants.

The use of avoidance areas as a siting criterion resulted from the Decontamination Assessment for Land and Facilities (DALF) at RMA (USATHAMA, 1984). In the DALF, long-term dedicated land uses were identified and contaminated areas were mapped and later confirmed through Contamination Assessment Reports (Appendix I). For example, by excluding Basin F in the site selection process, a major cost is avoided due to siting a land disposal facility where large volumes of contaminated material would be handled twice; that is, Basin F contaminated materials would first be excavated and temporarily stored at a different location, then finally moved back to the disposal facility. A similar rationale applies to avoiding dedicated land uses; for example, avoiding coincident siting with North Plants eliminates the need to move or demolish existing structures prior to construction of a disposal facility.

Maximum Area Criterion

The last site selection criterion, shown in Table 3-1, is the requirement to identify a large enough site to accommodate the estimated volume of 16 million ccy of material that the disposal facility will be designed to accept. This volume estimate is based on the best available information at the date of this writing as discussed in Appendix I. One thousand acres was used as an initial target based on a conservative scaleup from an earlier study (IT Corporation, 1984). When it became apparent that no site as large as 1,000 acres could be identified that satisfied all the criteria, facility layouts were prepared for the smaller identified sites to establish their capacity and hence their viability as candidate sites. The siting strategy became to locate the largest site meeting the criteria in Table 3-1 in

order to provide the greatest flexibility in facility design. It is shown in Chapter 6 that this volume estimate, and hence the initial 1,000-acre size criterion, did not constrain the facility design.

The RMA data used to implement these criteria are discussed in the section on siting methods below. Additional considerations that are site specific in nature are deferred to Section 3.7, where site characterization is discussed. Where adequate data do not exist to implement site selection criteria, recommendations are made in Section 3.7 for site characterization studies.

3.4 SITING ASSUMPTIONS

Since the site selection process necessarily preceded the facility layout effort, certain assumptions were required in addition to siting criteria. Four basic assumptions used in the site selection process are shown in Table 3-2.

The first siting assumption concerns facility shape. It is assumed that the waste cells can be arranged to fit a variety of facility shapes so that facility shape does not constrain the site selection process.

A second assumption is that one contiguous site is preferred over two or more sites. One site would have less perimeter length than two or more sites, which would reduce the number of monitoring wells necessary. If one contiguous site meeting all of the siting criteria cannot be identified, then two sites would be acceptable. As a result of the site selection process, two sites could be recommended, a first choice site and a second choice site that would act as a backup or overflow site if more area was needed. The two recommended sites need not meet identical criteria so long as it is clear that they are the best available sites.

A third assumption is that the site should be away from high density population areas surrounding the Arsenal and in an area in which the

TABLE 3-2

RMA LAND DISPOSAL FACILITY SITE SELECTION ASSUMPTIONS

Subject	Assumption
Facility Shape	Facility shape depends on waste cells arrangement and therefore does not constrain site selection.
Number of sites	One contiguous site is preferred over two or more sites to minimize perimeter length. Minimum perimeter lowers monitoring costs.
Current and Projected Land Use	It is desirable to site away from current off-site high density population and to site on areas that are compatible with projected on-site land uses.
Waste Centroid	The volume-distance weighted average for the 40 largest suspected contaminated sites was calculated to be near the Basin A Neck in the northwest corner of Section 36 (Appendix I.8). It is assumed to be favorable to site near this centroid to minimize hauling distance, handling time and costs, and also possible adverse health and safety effects.

disposal facility is compatible with projected land uses on and around the Arsenal. Current and projected land uses on and around the Arsenal will be discussed as a site characterization topic in Section 3.8. Existing or projected population will be used to evaluate alternative sites in Section 3.7. Also, avoidance of present dedicated land-use areas on the Arsenal is a site selection criterion that should not be confused with population nor with projected on-site land uses.

The fourth assumption used in the siting process involves siting near the waste centroid. The calculation of the waste centroid is discussed in Appendix I. The waste centroid represents the center of volume of forty suspected contaminated sites on the Arsenal that involve volumes in excess of 20,000 bank cubic yards (bcy). It is assumed to be favorable to site near this centroid to minimize hauling distance and handling time and costs, as well as health and safety impacts. The actual costs associated with the recommend site(s) are discussed in Chapter 7. Health and safety issues are discussed in the operational plan in Appendix III.

Additional considerations in the site selection process are discussed in Section 3.7 under site recommendation, and Section 3.8 under site characterization.

3.5 SITE SELECTION METHODS

Approach

The site selection method is a map overlay process as shown in Figure 3-1. The first step in the site selection process was to establish a source map database for geologic and geographic information that has widespread acceptance. References for the source maps used in site selection are included in the discussion of each criterion map below.

Because a need to create new data maps with a large number of iterations was anticipated, a Geographic Information System (GIS) was used to combine database management with computer-aided mapping. The

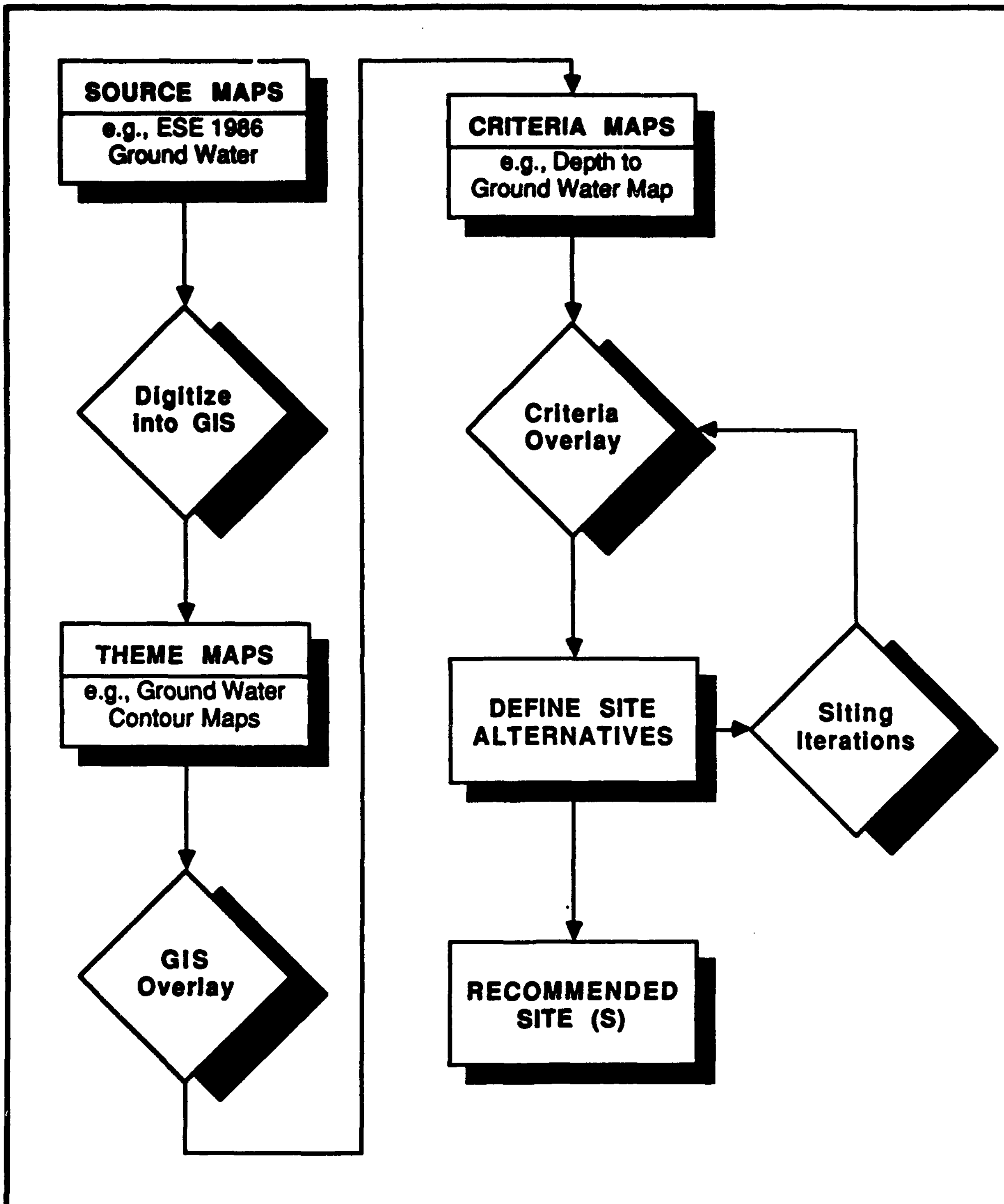


Figure 3-1
RMA SITE SELECTION PROCESS

Prepared for:
U.S. Army Program Manager's Office
Rocky Mountain Arsenal Contamination Cleanup
Aberdeen Proving Ground, Maryland

source maps were digitized into the GIS through electronic capture of the map features. Computer-generated check plots were produced and compared to the original source maps to ensure accurate data capture. As map data were entered into the GIS, information was organized into map themes. For example, the avoidance area map theme included a combination of suspected highly contaminated areas such as South Plants and Basin A, and dedicated land use areas such as the North Plants buildings and the groundwater intercept systems.

Theme maps were then overlaid with the GIS to produce criteria maps. Some criteria maps were derived or calculated from map themes. For example, the depth-to-groundwater criteria map was calculated from the overlay of the surface topography elevation map (ACOE 1984) with the groundwater elevation map (ESE 1986), thereby producing a map of the difference in elevations. The depth-to-groundwater criteria map was then used to define the site alternatives along with other criteria as shown in Figure 3-1.

The siting criteria shown in Table 3-1 were overlaid in the GIS in an iterative manner to define site alternatives. The siting iterations involved finding areas that simultaneously satisfied one siting criterion in combination with one or more of the other criteria. The depth-to-groundwater criterion was varied in increments of 10 foot depths as described below. The site selection process resulted in the location of site alternatives on a map and the definition of site criteria met by each alternative.

Relative weights were not used to trade off site criteria in the iterative-overlay process for defining site alternatives; therefore, all criteria were equally weighted. Weights were not used because there is no present basis, either regulatory or cost controlled, for determining unit values of the criteria. Computer optimization programs were also not used because information from previous studies indicated the GIS would produce adequate results with the small number of criteria used here.

Ten site alternatives, each meeting at least two criteria, were initially identified through the iterative criteria map overlay process. These ten alternatives were screened down to four alternatives by requiring that three criteria be simultaneously satisfied. All ten site alternatives are presented in this report. Two of these site alternatives were used in the design phase of this study based on consideration of the unsaturated alluvium criterion and additional factors that were not included as siting criteria as discussed in Section 3.8.

Sand Channels on RMA

The presence of sand channels on the bedrock surface was not mapped in the site selection overlay process. Sand channels in the bedrock surface at RMA have been postulated to provide conduits for accelerated leachate migration by hydraulically connecting the alluvial and bedrock aquifers (Crabtree & Thompson, 1983). For these reasons, an extensive search was performed to find acceptable Arsenal-wide maps of sand channels. While sand channels have been mapped in various areas around RMA, including Basin A and the north boundary, there are no studies underway or already complete that have mapped sand channels for the entire Arsenal. Discussions with RMA project geologists and PMSO staff with extensive RMA experience indicate that the significance of sand channels beneath a specific site can only be evaluated as part of a detailed site investigation of the local subsurface geohydrologic regime.

Consequently, screening the entire RMA for sand channels is not a practical approach. Considerations of hydraulic head, detailed bedrock and groundwater elevations, and the sometimes complex interactions between bedrock and alluvial aquifers can only be effectively evaluated on a site-specific basis. Recommendations for further site-specific characterization studies, using geophysical techniques, are included in Appendix V.1.

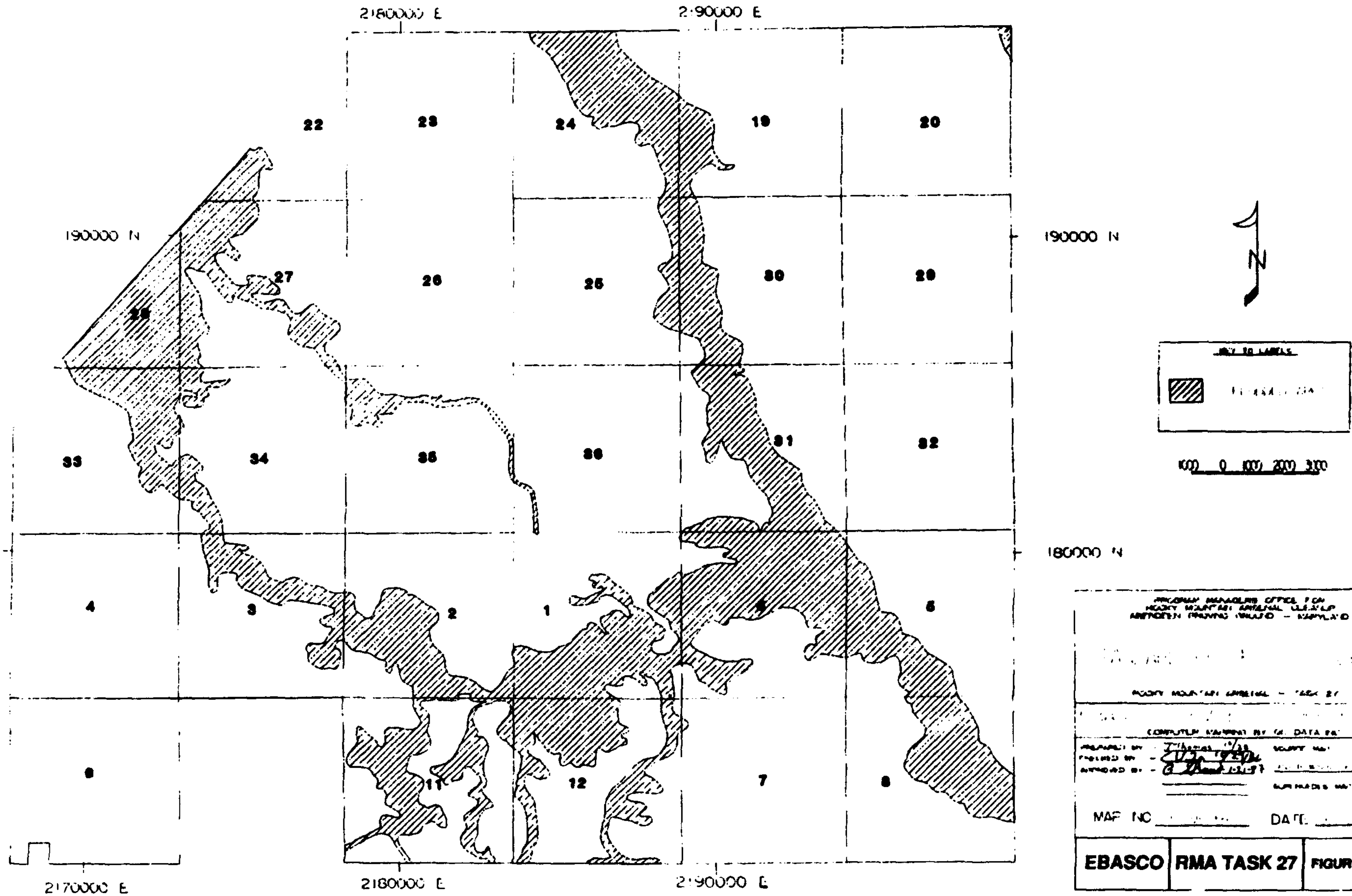
Criteria Maps

Criteria maps were produced for the siting criteria in Table 3-1, excluding size and Holocene faults. The size siting criteria is dependent on the spatial discrimination of the other five criteria. To identify this relative discrimination, each criterion was first mapped separately on the computer graphics screen of the GIS as shown in Figures 3-2 through 3-5.

Holocene faults, as discussed above (Section 3.3), were not mapped as a siting criterion because Holocene faults do not preclude siting a disposal facility anywhere on the Arsenal. The Holocene fault criteria, therefore, is not included in the remaining discussion on identifying alternative sites. All alternative sites identified below consequently automatically satisfy the seismicity criterion, one of the mandatory siting criteria (Crabtree & Thompson, 1983).

The only other mandatory siting criteria, the Standard Project/100-year floodplain, is shown in Figure 3-2. The floodplain extends from the southeastern corner of the Arsenal along First Creek up to the northern boundary. The floodplain also extends to the west passing just south of the South Plants area and through the western tier along the Irondale Gulch. A very small portion of the floodplain from Second Creek encroaches on the extreme northeast corner of the Arsenal (McCain & Hotchkiss, 1975). It is important to notice the lack of coincidence between the floodplain and two of the three largest areas identified from the 40 foot depth-to-groundwater map, Figure 3-3. The North Plants and eastern boundary areas are not covered by the floodplain, while the western tier area is bisected by the floodplain in Sections 3 and 34. The groundwater and floodplain criteria maps are combined later in this report into one map to define site alternatives.

The depth-to-groundwater parameter was first reviewed in increments of 10 feet, starting with the greatest depths observed, to identify on an Arsenal-wide basis whether any substantial areas exist that exceed the 40 feet criterion. Areas as large as 400 acres were mapped at



PROGRAM MANAGER'S OFFICE FOR ROCKY MOUNTAIN ARSENAL CLEANUP ABERDEEN PROVING GROUND – MARYLAND

ROCKY MOUNTAIN ARSENAL – TASK 27

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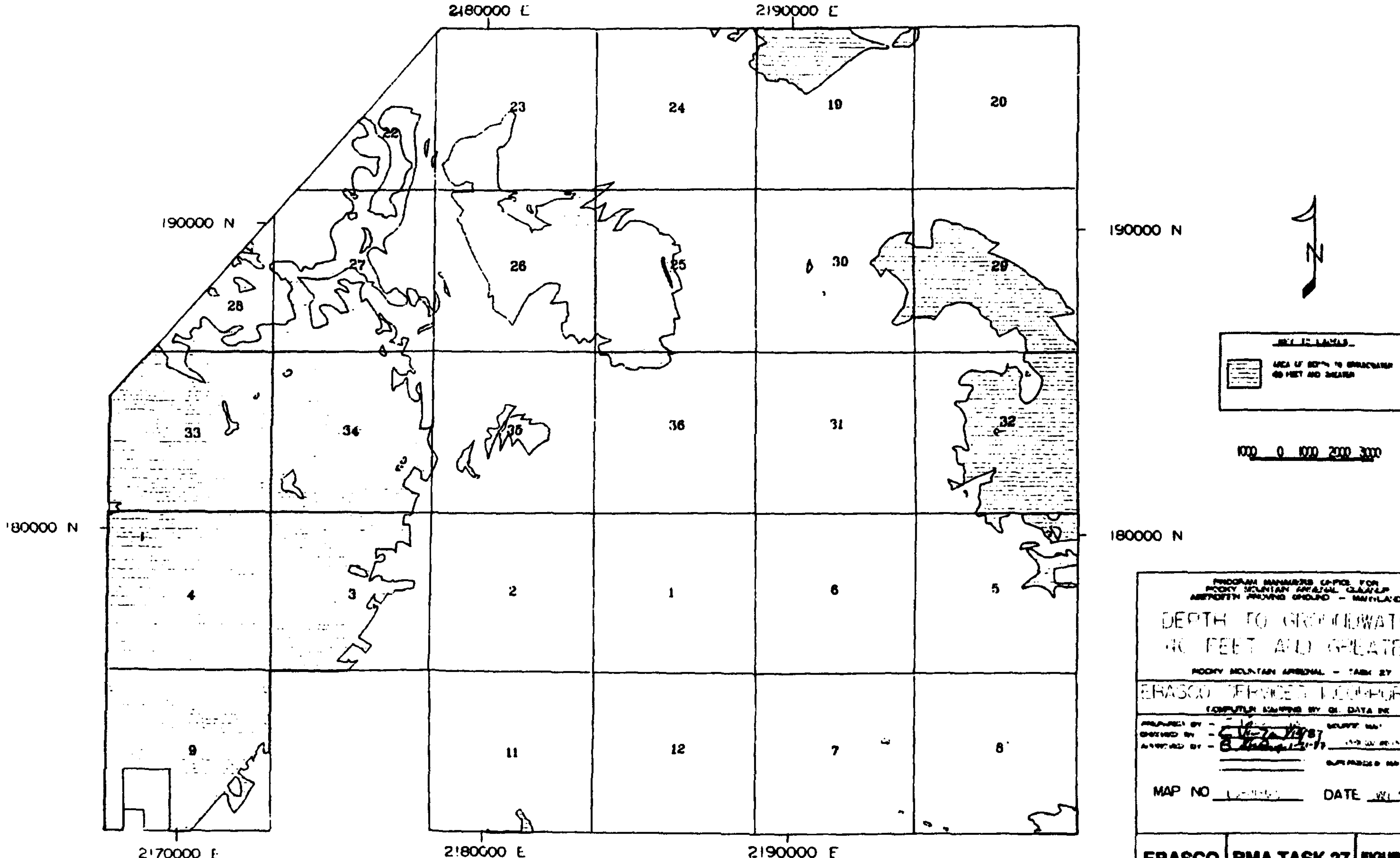
EBASCO	RMA TASK 27	FIGURE 3-2



PROGRAM MANAGER'S OFFICE FOR
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ABERDEEN PROVING GROUND - MARYLAND

DEPTH TO GROUNDWATER
40 FEET AND GREATER

ROCKY MOUNTAIN ARSENAL - TASK 27

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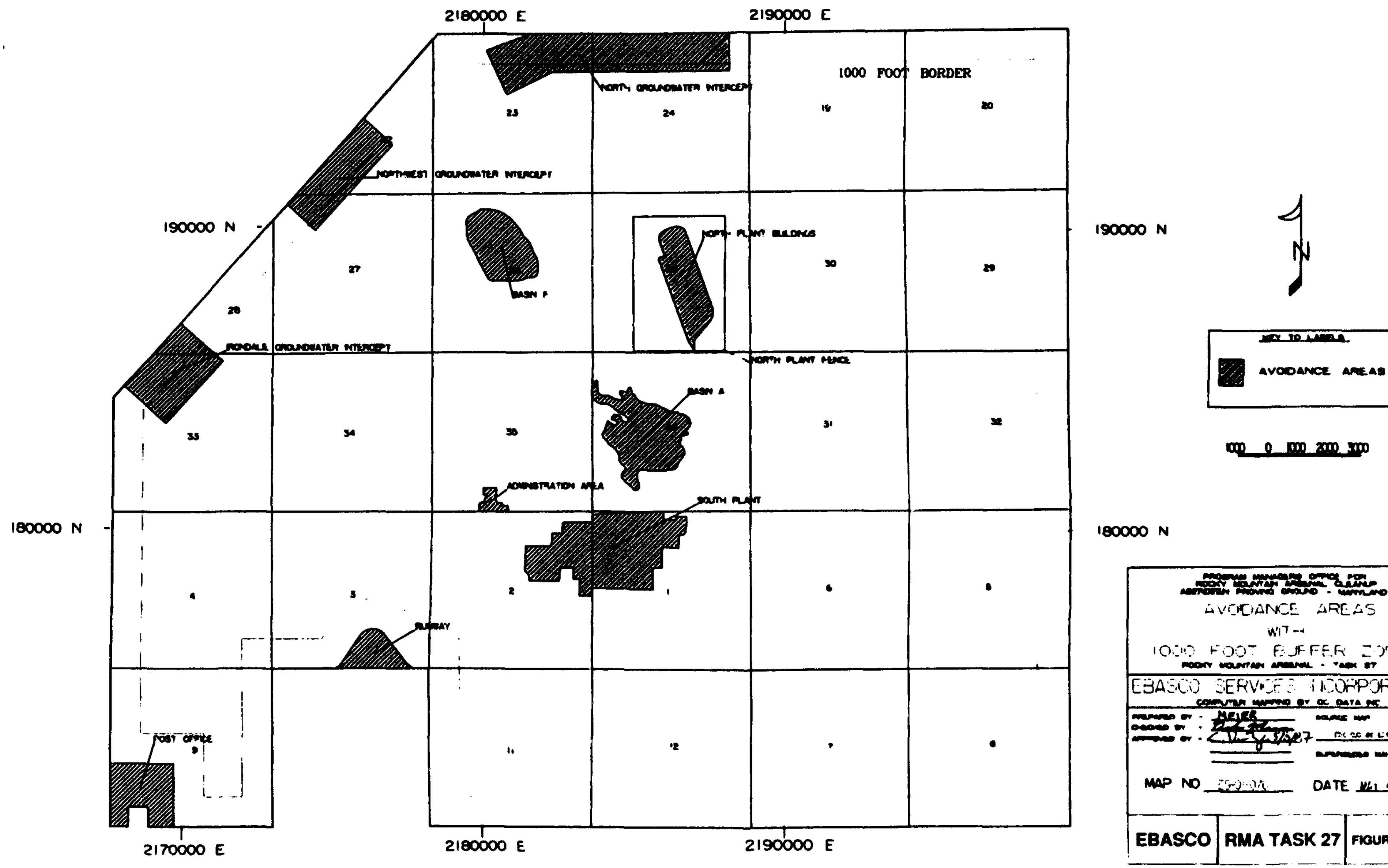
EBASCO	RMA TASK 27	FIGURE 3-3



PROGRAM MANAGERS OFFICE FOR
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ABERDEEN PROVING GROUND - MARYLAND

AVOIDANCE AREAS
WITH
1000 FOOT BUFFER ZONE

ROCKY MOUNTAIN ARSENAL - TASK 27

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CHECKED BY :
APPROVED BY : 3/5/87

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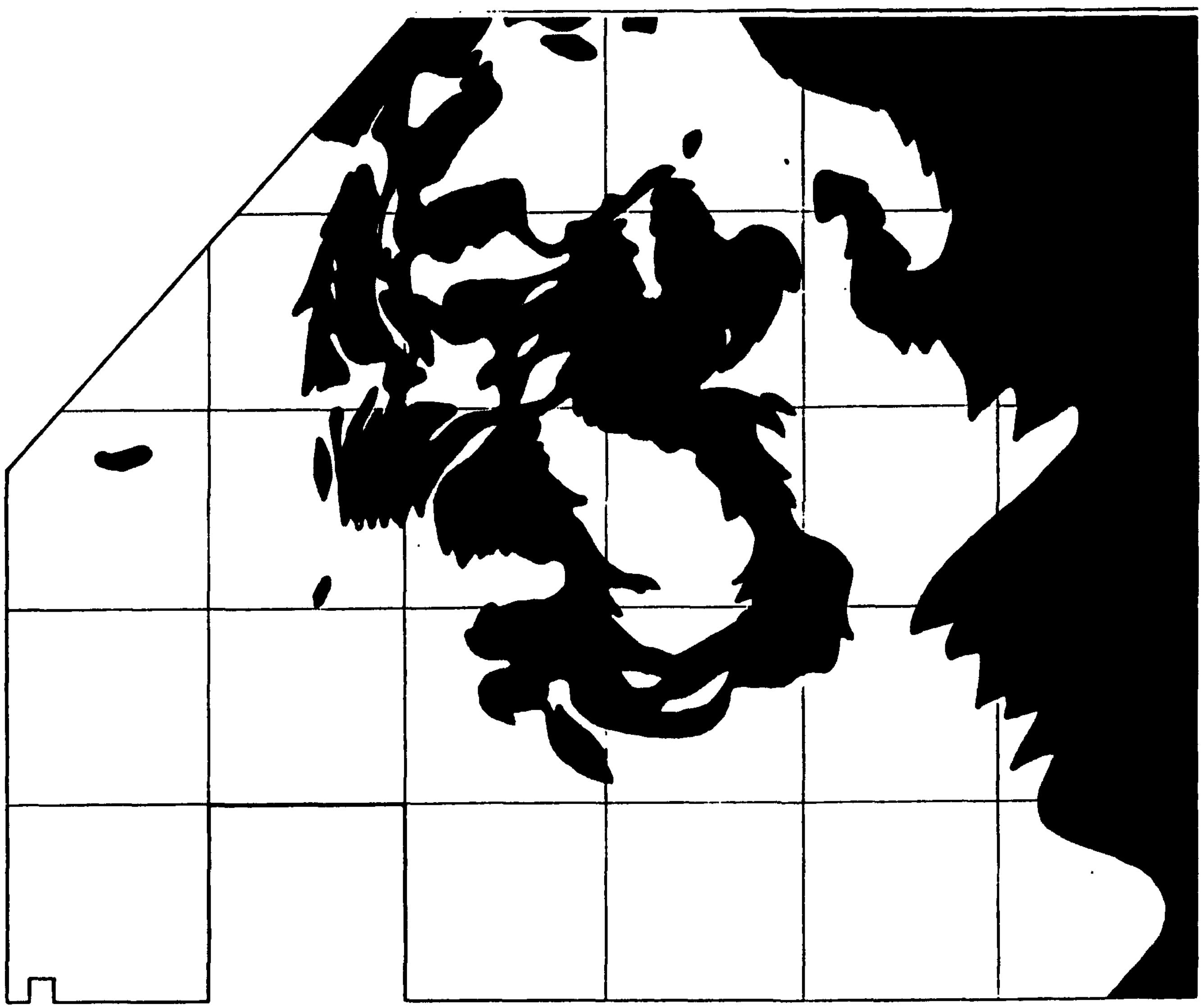
EBASCO	RMA TASK 27	FIGURE 3-4



SCALE: 1 INCH EQUALS 3000 FEET

BEDROCK RELATIVE TO GROUNDWATER

EBASCO SERVICES INCORPORATED

PREPARED BY: T. Thomas

MAP NO. ES-01-043 DATE OCT 31 1986

EBASCO	RMA TASK 27	FIGURE 3-5

60 feet and greater depth-to-groundwater. Closely spaced areas aggregating 1,000 acres were mapped at 50 foot and greater depth-to-groundwater, but these areas were not contiguous. Figure 3-3 shows the 40 foot and greater depth-to-groundwater map, on which contiguous areas approaching or exceeding 1,000 acres appear. The three largest contiguous areas can be identified in Figure 3-3 as: the large area on the west side of the Arsenal is referred to herein as the western tier; the area near North Plants and Basin F in Sections 25 and 26 is referred to as North Plants; and the area on the eastern boundary of the Arsenal is referred to as the eastern boundary. These three locations will be referred to by these names in the rest of the chapter.

Avoidance areas and the 1,000 foot buffer zone are shown in Figure 3-4. Avoidance areas include Basin F, North Plants area, North Plar . buildings, Basin A, and South Plants. Avoidance areas also incluc. the dedicated land use areas of the Post Office, Stapleton airport runway, and the Irondale, Northwest, and North boundary groundwater intercept systems. An arbitrary 500 foot buffer zone was designated around the intercept systems to avoid conflicts with maintenance near the systems. The 1,000 foot buffer zone, providing a fixed distance away from the edge of the Arsenal, is also shown in Figure 3-4.

Figure 3-5 shows bedrock elevation (Campbell & Witt, 1983) relative to groundwater elevation. Unshaded or white areas of Figure 3-5 represent groundwater above bedrock (i.e., areas of saturated alluvium). Shaded areas represent favorable siting conditions where the bedrock is above the groundwater elevation (i.e., areas of unsaturated alluvium). The large contiguous areas of unsaturated alluvium occur near North Plants and on the eastern boundary. The western tier is completely underlain by saturated alluvium.

3.6 SITING RESULTS

The siting criteria from Table 3-1 (excluding Holocene faults and size) were combined to initially produce 10 site alternative⌃ at the three general locations on the Arsenal. These 10 alternatives are shown in Table 3-3. As identified above, the three locations are North Plants, Western Tier, and the eastern boundary. There could be more than one site at each location because different combinations of criteria resulted in variations on boundaries at each location. Each location as shown in Table 3-3 will be discussed with alternative sites designated by a number and/or letter. The most acceptable alternative or group of alternatives are identified at each location in the discussion below before preceding onto the next location.

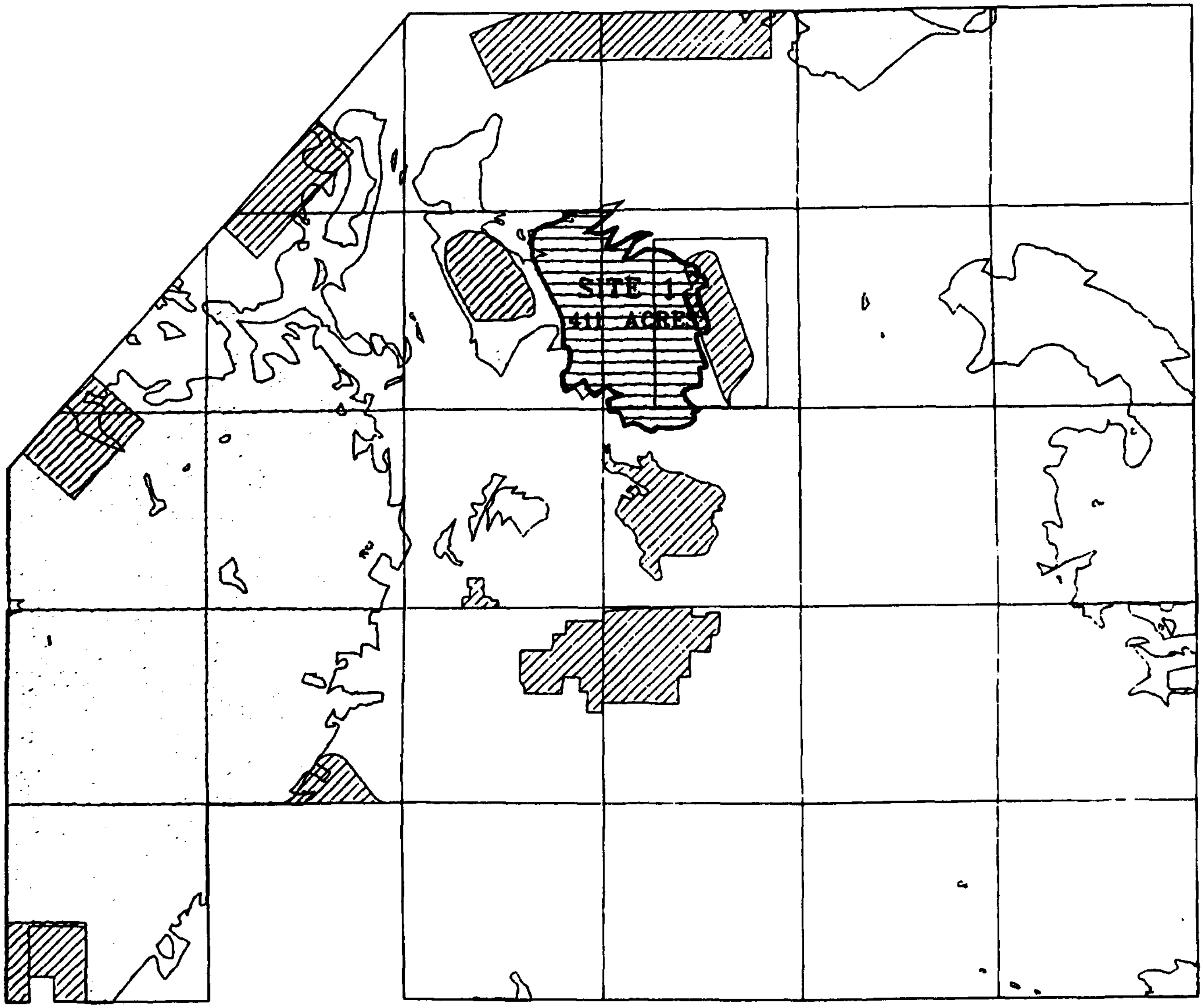
North Plants

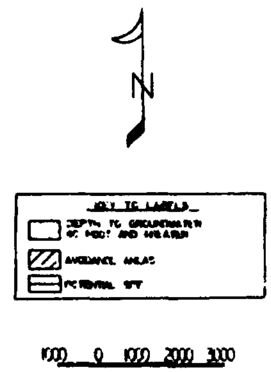
With reference to the siting parameters in Table 3-1, Figure 3-6 shows the combination of 40 foot and greater depth-to-groundwater to define Alternative Site 1. Site 1 was calculated by the GIS to cover 411 acres (the apparent numerical precision of GIS calculated areas is deceptive as it is not warranted by the data nor the calculation method; Site 1 may be considered to be 400 acres more or less). Figure 3-6 shows however that Site 1 partly overlies the North Plants avoidance area. A modification of Site 1 to avoid coincidence with the North Plants area is shown as Site 1A in Figure 3-7. Site 1A covers a correspondingly smaller area of roughly 300 acres, a reduction of 110 acres from Alternative Site 1. In an effort to increase the size of the site while minimizing the interference with the North Plants area, Site 1B (Figure 3-8) was developed, which encroaches on the North Plants boundary but completely avoids the North Plants buildings, since the North Plants boundary only consists of a fence surrounding the North Plants buildings. Site 1B provides a larger area than Site 1A while maintaining a 40 foot depth to groundwater and avoiding coincidence with North Plants buildings. It should also be noted that Sites 1, 1A, and 1B are one mile (exceeding the 1,000 foot criterion) from the edge of the Arsenal and do not coincide with the floodplain.

TABLE 3-3

SITE ALTERNATIVES AND SITING CRITERIA

Alternative Site Number	Depth to groundwater (ft.)	Avoid Floodplain	1,000-ft Minimum Buffer Distance	Avoid Dedicated Use Areas, Etc.	Avoidance of Saturated Alluvium (Percent of Area)	Approx. Size, Acres
Location: North Plant/Basin F						
1	≥40	Yes	Yes	No	90	410
1A	≥40	Yes	Yes	Yes	90	300
1B	≥40	Yes	Yes	Yes	90	400
2	≥30	Yes	Yes	No	60	860
2A	≥30	Yes	Yes	Yes	60	710
Location: Western Tier						
3	≥40	No	Yes	Yes	20	1,500
4	≥40	No	Yes	Yes	20	440
5	≥40	Yes	Yes	Yes	20	1,150
Location: Eastern boundary						
6A	≥40	Yes	Yes	Absent	100	300
6B	≥30	Yes	Yes	Absent	90	1,060





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ABERDEEN PROVING GROUND - MARYLAND

ROCKY MOUNTAIN ARSENAL - TASK 27

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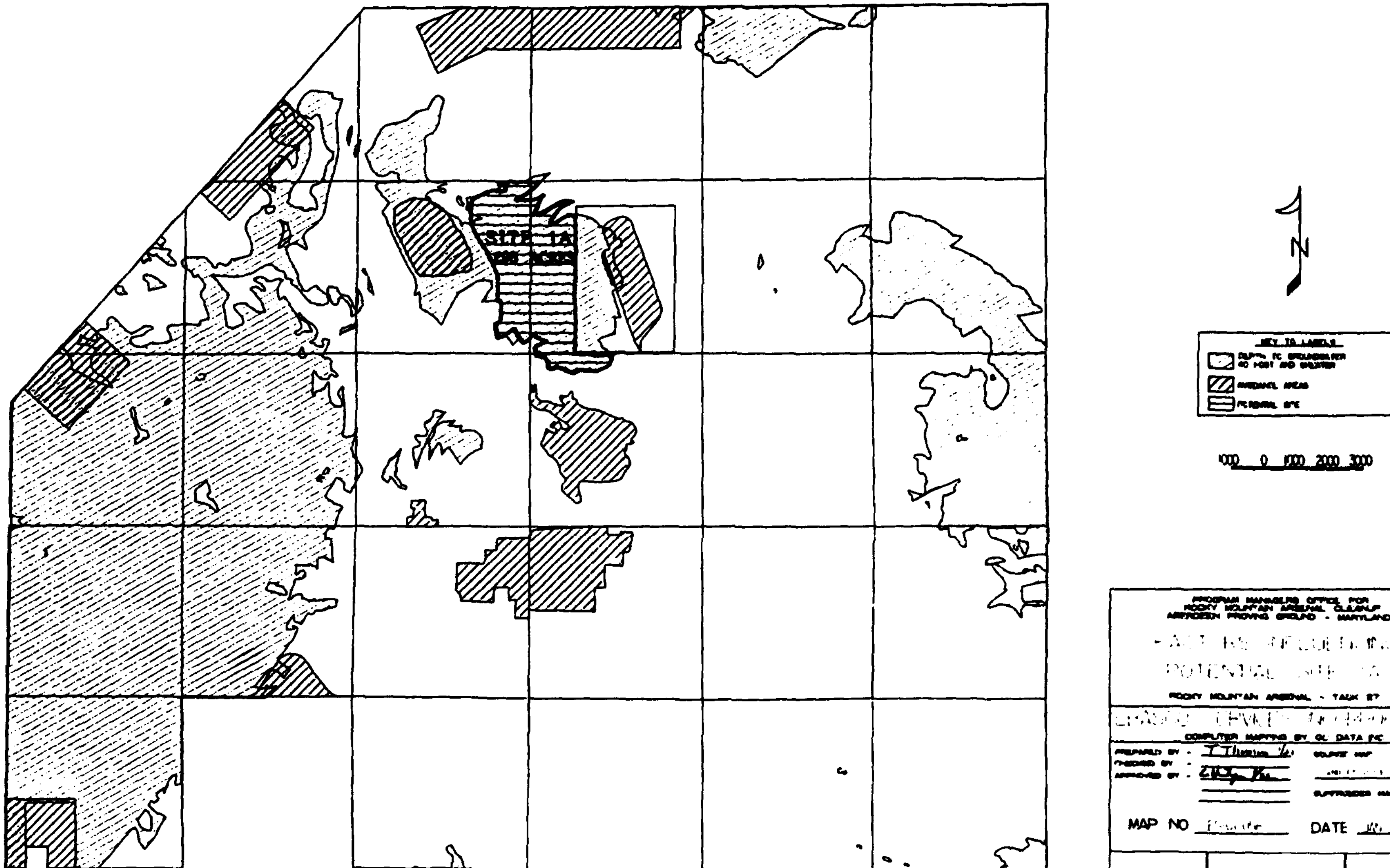
EBASCO	RMA TASK 27	FIGURE 3-6



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ABERDEEN PROVING GROUND - MARYLAND

ROCKY MOUNTAIN ARSENAL - TASK 27

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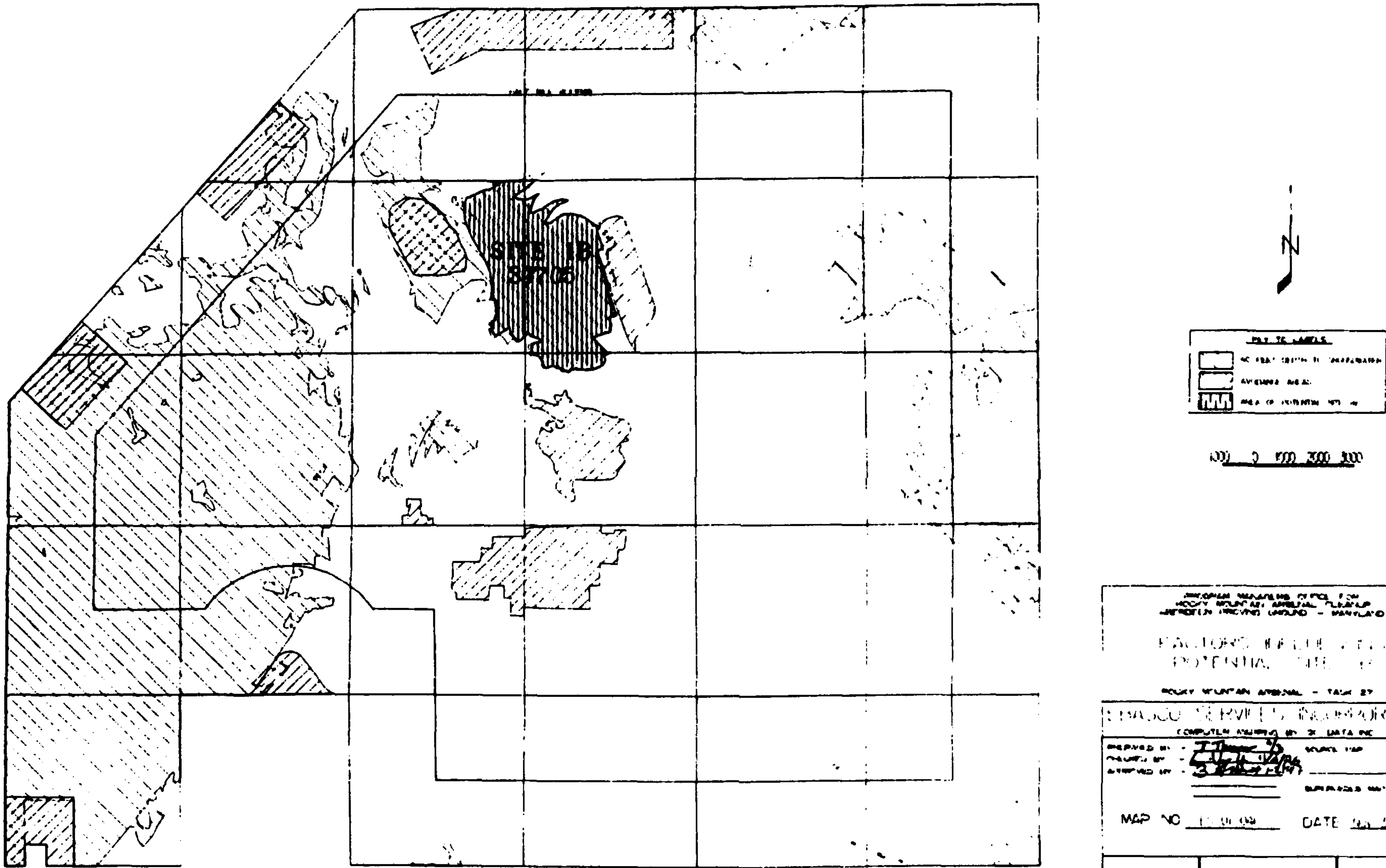
EBASCO	RMA TASK 27	FIGURE 3-7



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EBASCO	RMA TASK 27	FIGURE 3-8

Site 1B, however, lies partly on an area of saturated alluvium as shown in Table 3-3 and Figure 3-15.

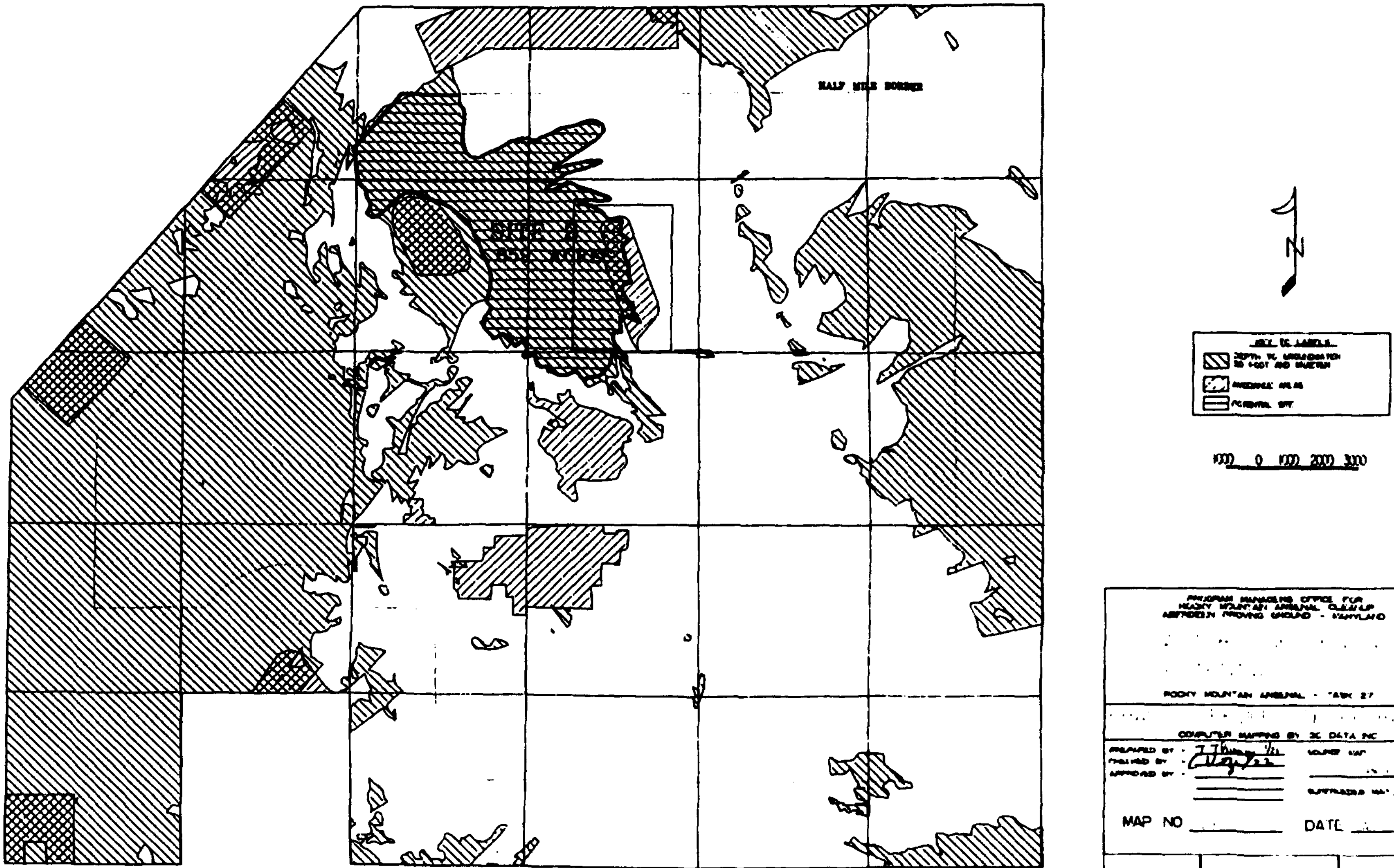
Figure 3-9 shows a combination of the 30 foot and greater depth-to-groundwater map and an arbitrary one-half mile buffer to define Alternative Site 2. Site 2 was calculated to cover approximately 860 acres, more than twice the size of Sites 1, 1A, or 1B. Site 2, however, also coincides with the North Plants area. Figure 3-10 shows Alternative Site 2A with no coincidence with the North Plants area, and a corresponding decrease in size to roughly 700 acres. Site 2A is larger than Site 1B, but of the two, Site 1B is preferred because of the greater depth to groundwater of 40 feet.

Western Tier

Figure 3-11 shows Site 3 defined by the 40 foot and greater depth-to-groundwater map and an arbitrary one-half-mile buffer zone. Site 3 covers approximately 1,500 acres. Since this area is at least 50 percent larger than necessary, a more restrictive arbitrary one-mile buffer zone was combined with the 40 foot and greater groundwater map to define Site 4 as shown in Figure 3-12. Site 4 covers 436 acres; to attain a larger area than Site 4, a one-half-mile buffer, 40 foot depth-to-groundwater, and the floodplain are combined in Figure 3-13 to define Site 5. Site 5 is made up of two noncontinguous parcels that are divided by the Irondale Gulch portion of the floodplain. Site 5 covers 1,146 acres as calculated by the GIS and does not coincide with any avoidance areas or with the floodplain. Of the three alternatives on the western tier, Site 5 appears to be the most favorable. It does, however, lie over a major area of saturated alluvium, as shown in Table 3-3 and Figure 3-16.

Eastern Boundary

Figure 3-14 shows the 40 foot and greater depth-to-groundwater map in combination with the 1,000 foot buffer to define Site 6A. Site 6A



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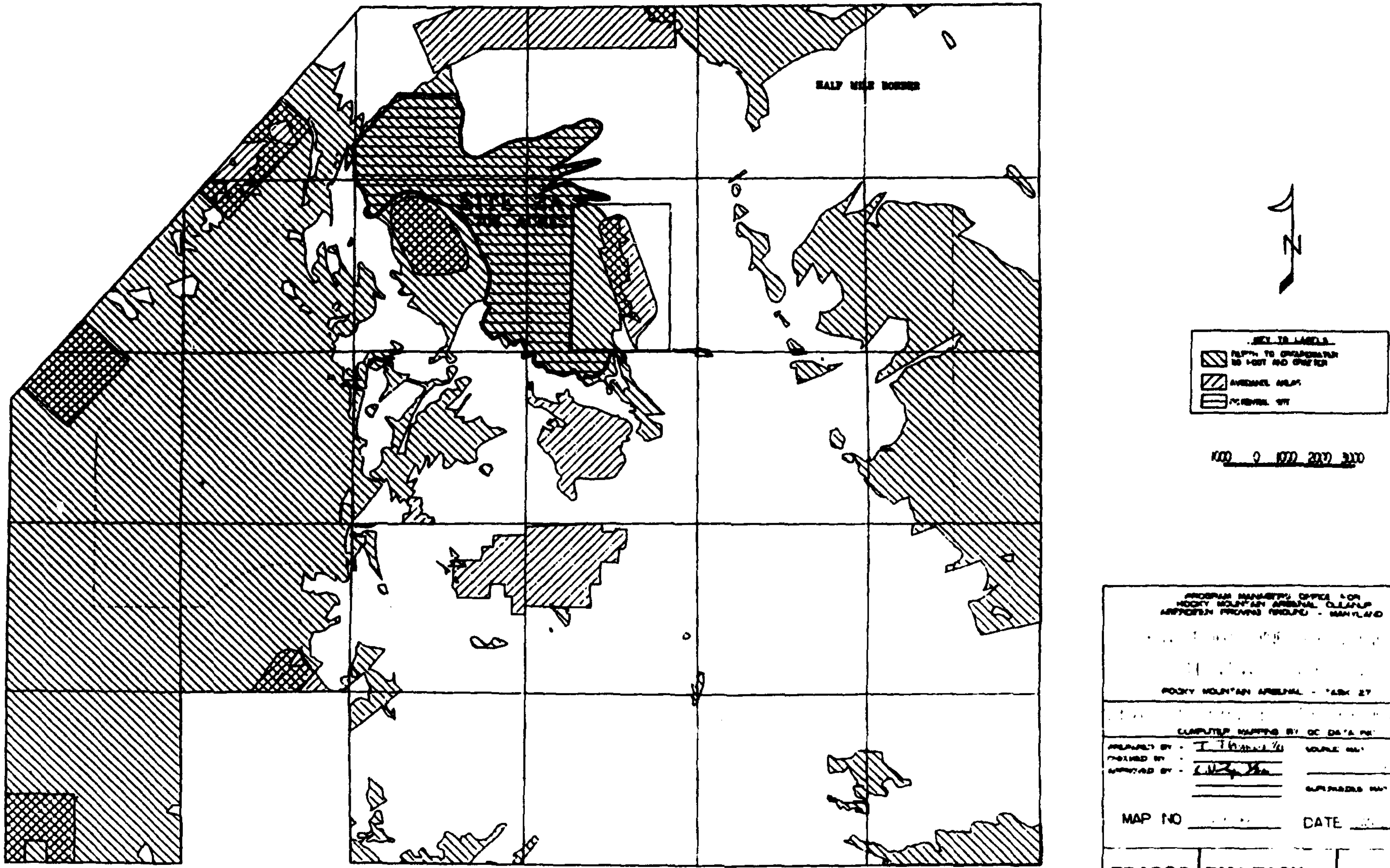
EBASCO | RMA TASK 27 | FIGURE 3-9



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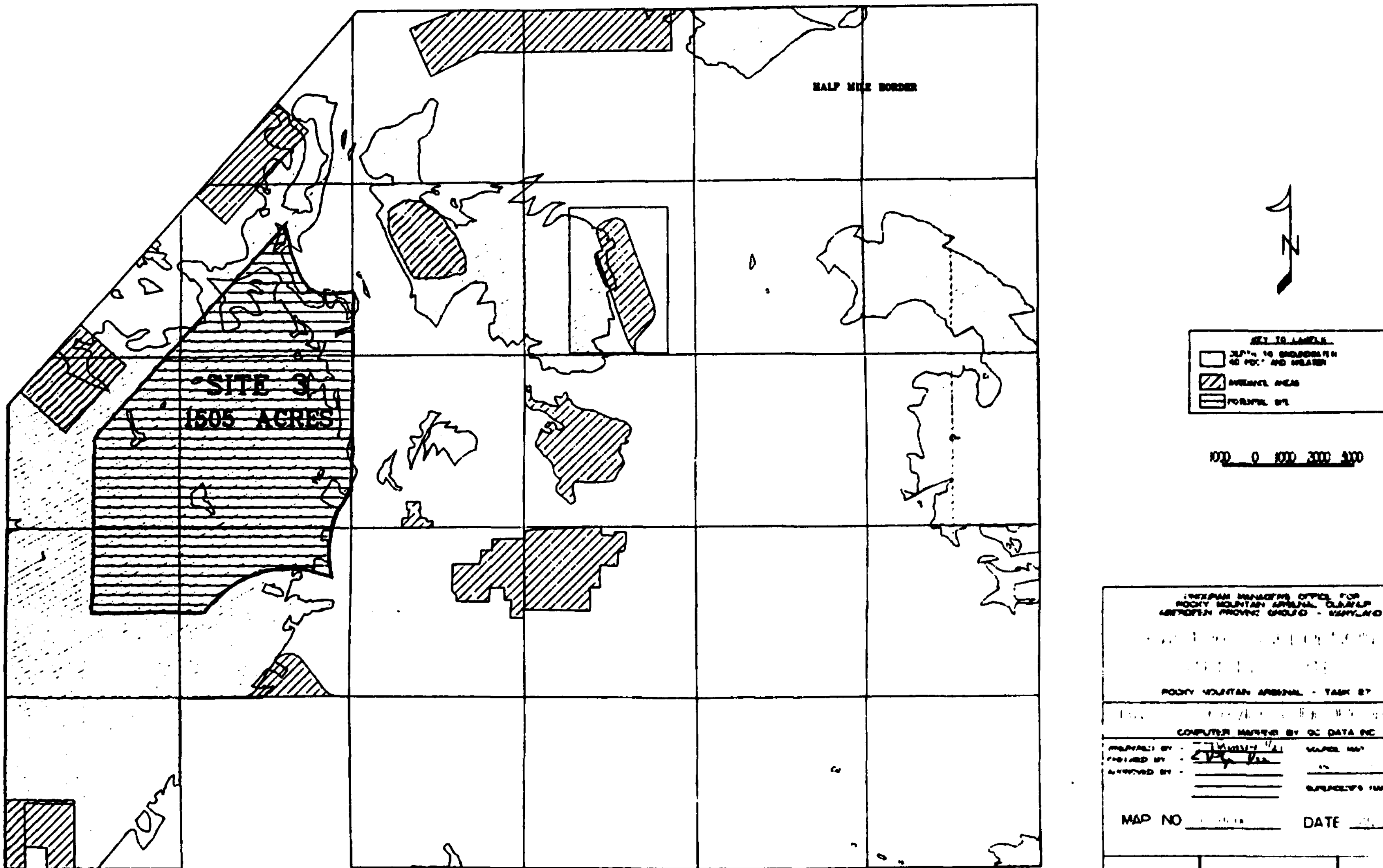
EBASCO	RMA TASK 27	FIGURE 3 - 10



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ROCKY MOUNTAIN ARSENAL - TASK 27

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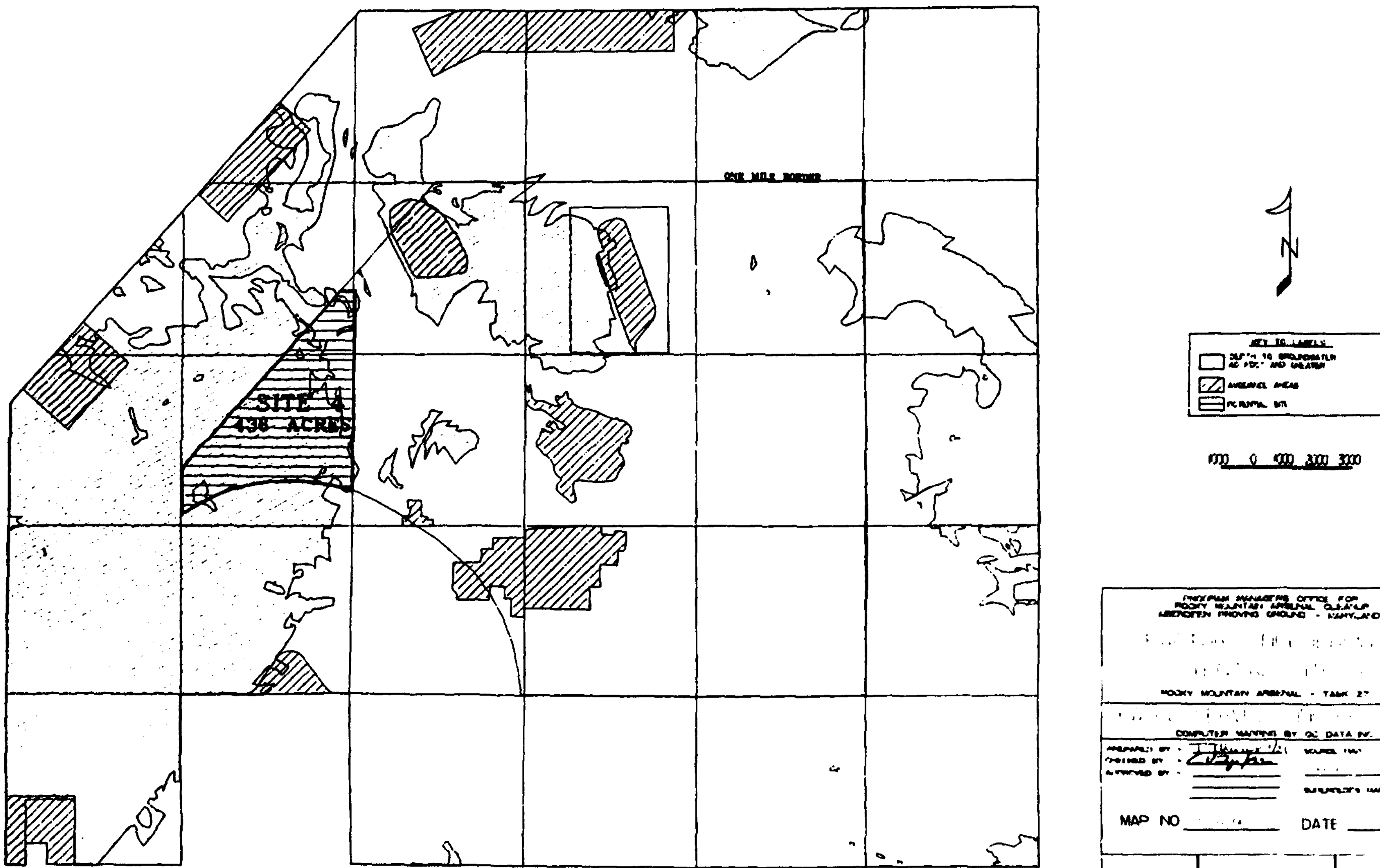
EBASCO	RMA TASK 27	FIGURE 3 - 11



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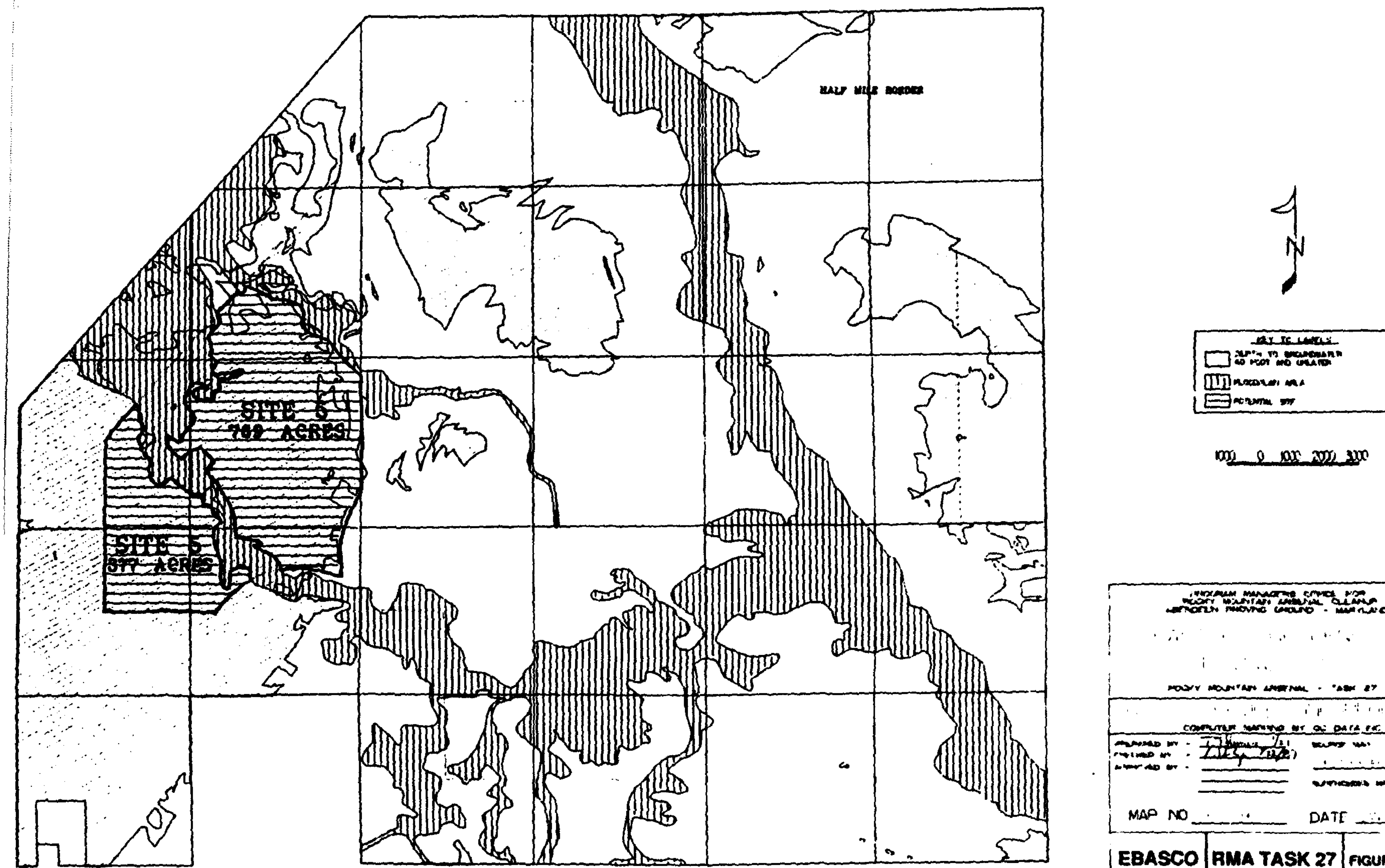
EBASCO | RMA TASK 27 | FIGURE 3 - 12



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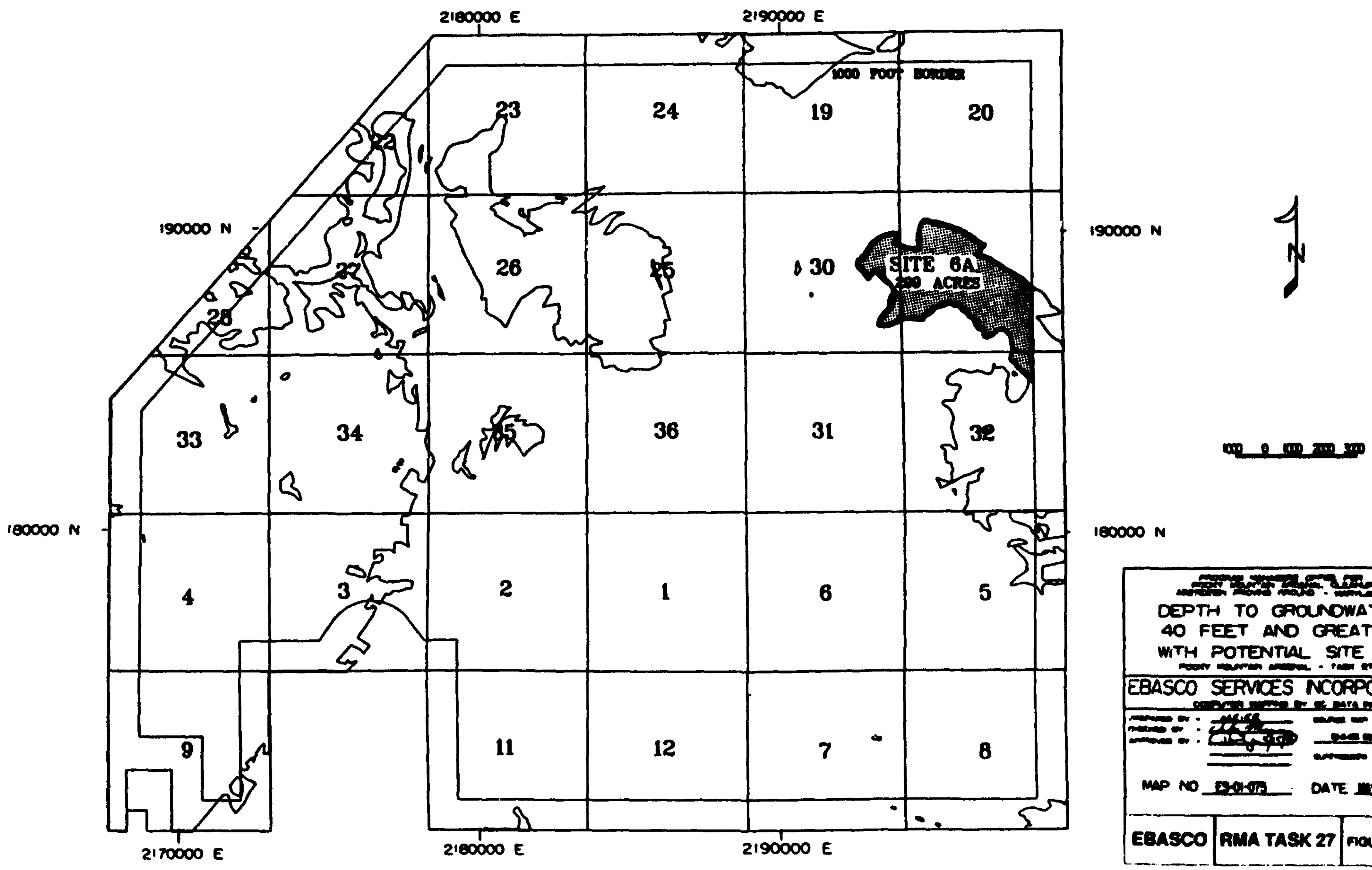
EBASCO	RMA TASK 27	FIGURE 3-13



DEPTH TO GROUNDWATER
40 FEET AND GREATER
WITH POTENTIAL SITE 6A

EBASCO SERVICES INCORPORATED

MAP NO E3-01-075 DATE MAY 14 1987

EBASCO	RMA TASK 27	FIGURE 3-14

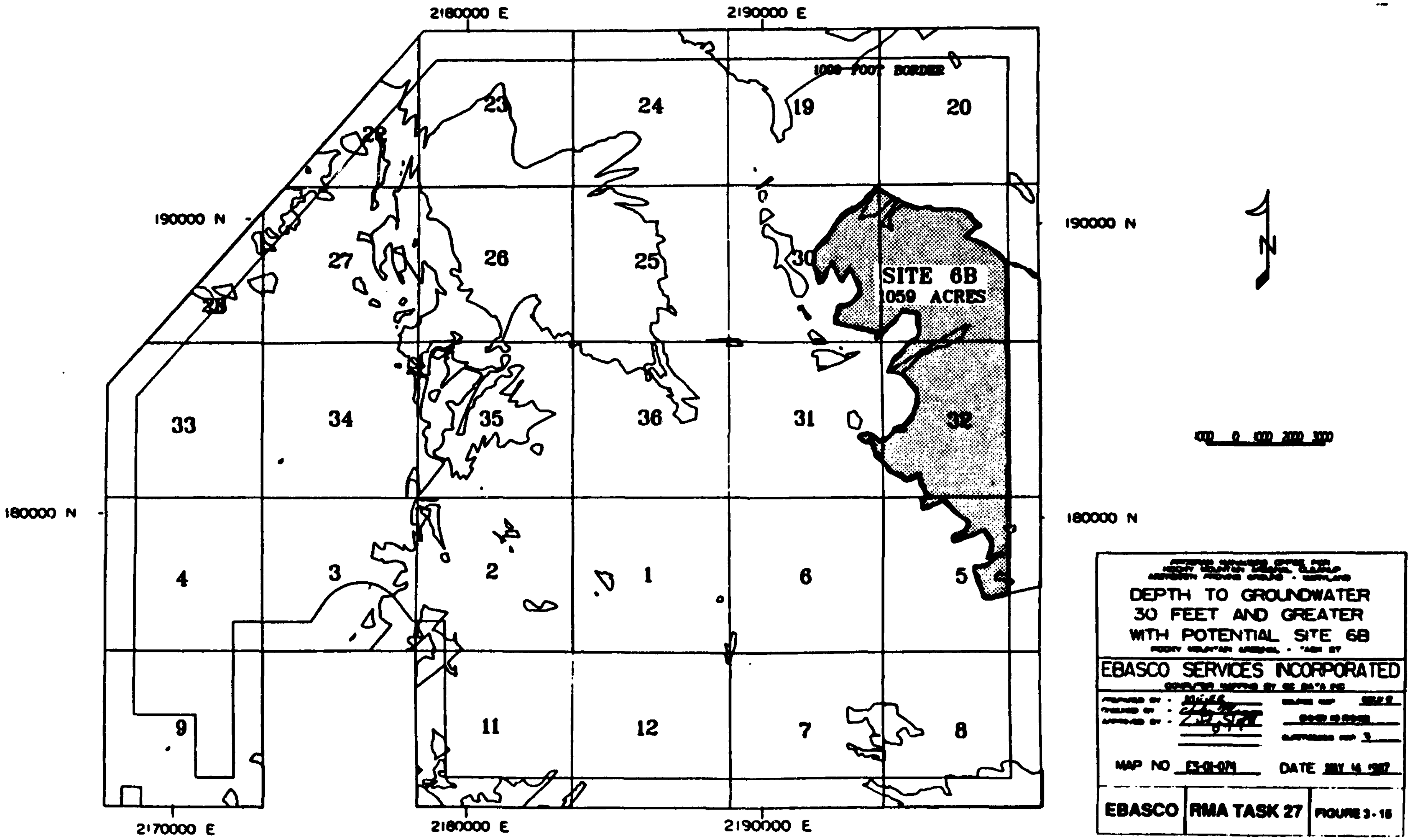
covers only 300 acres but does not coincide with the floodplain, avoidance areas, or areas of saturated alluvium. This small size was, however, determined to be too confining for complete facility layout.

Site 6B was defined by relaxing the depth-to-groundwater criterion from 40 feet to 30 feet. Site 6B was then defined as shown in Figure 3-15 by the 1,000 foot buffer zone, 30 feet depth to groundwater, and avoidance of floodplain. A small part of the site lies over saturated alluvium as seen in Figure 3-16. Site 6B includes an area of more than 1,000 acres as compared to the 300-acre size of Site 6A. The trade-off between this 10 foot reduction in depth to groundwater and site area will be addressed in the following section.

3.7 SITE RECOMMENDATION

By general location, Site 1B was preferred at North Plants, and Site 6B is preferred on the eastern boundary. The unsaturated alluvium siting criterion mapped in Figure 3-16 shows that Site 5 on the western tier is less favorable than Sites 1B and 6B because they are underlain predominantly by unsaturated alluvium. The geohydrologic setting of Site 1B is superior and it was subsequently determined (see Chapter 6) that the size of Site 1B was not a serious constraint for the facility design. In addition, Site 1B was closest to the waste centroid at the northwest corner of Section 36 (Table 3-2).

Site 1B, therefore, emerged as the preferred site since it very nearly meets all selection criteria and is very near the waste centroid. Site 1B is recommended as the primary site, with the suggestion that the backup or overflow site be 6B. The basis for suggesting 6B rather than 5 as the secondary site is as follows. Each has a geohydrologic drawback in that unsaturated alluvium underlies Site 5 and there is 10 feet less depth-to-groundwater (30 feet versus 40 feet) at Site 6B. While both sites are approximately the same distance away from the waste centroid, Site 5 on the western tier is located 1,000 feet (the buffer zone distance) from a high density population of more than 1,000 people per square mile in Commerce City, (Adams County, 1984). Site 6B



2180000 E
2190000 E
2170000 E
190000 N
180000 N
1000-FOOT BORDER
SITE 6B
1059 ACRES
23
24
19
20
28
27
26
25
30
33
34
35
36
31
32
4
3
2
1
6
5
9
11
12
7
8
N
DEPTH TO GROUNDWATER
30 FEET AND GREATER
WITH POTENTIAL SITE 6B
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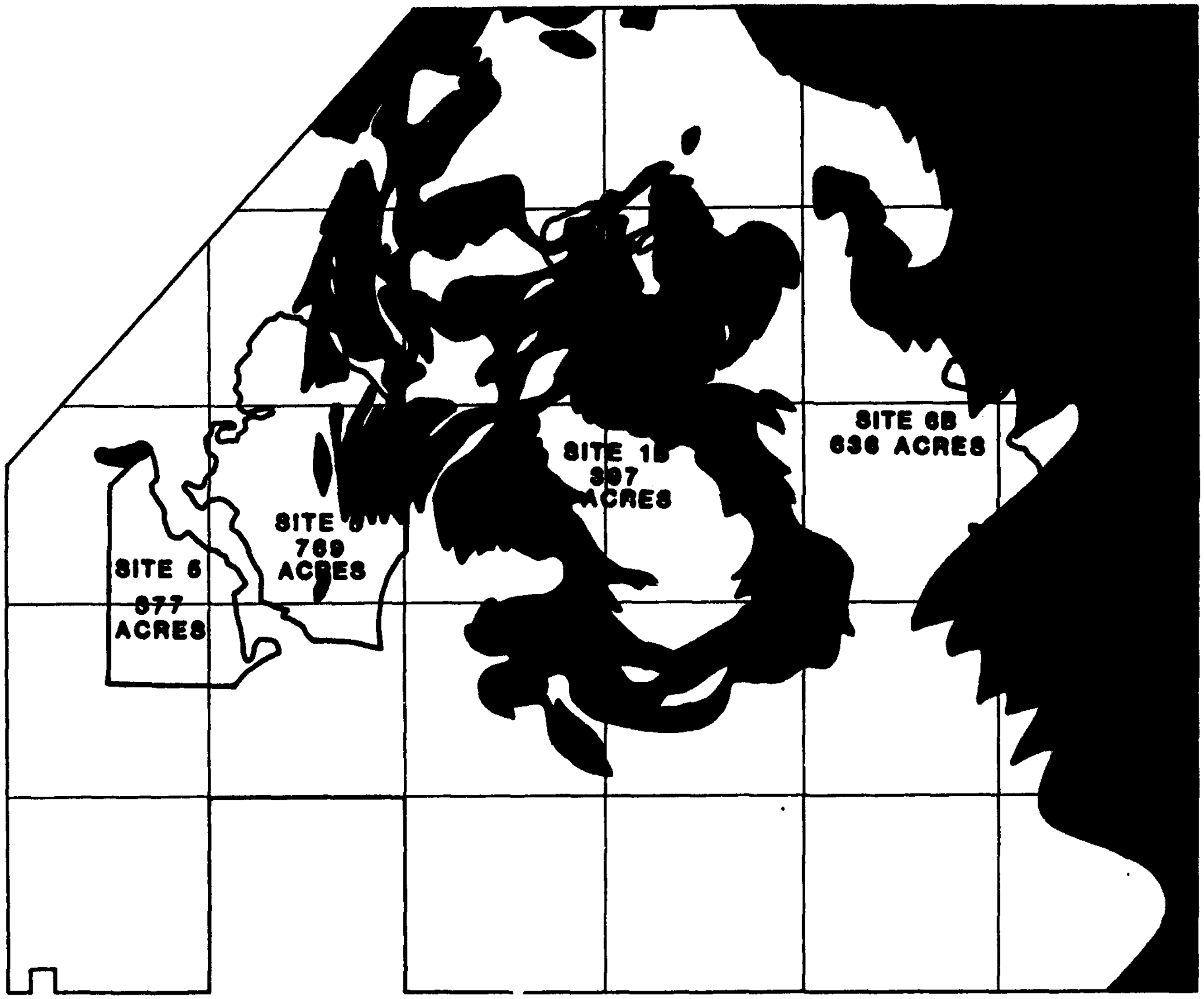
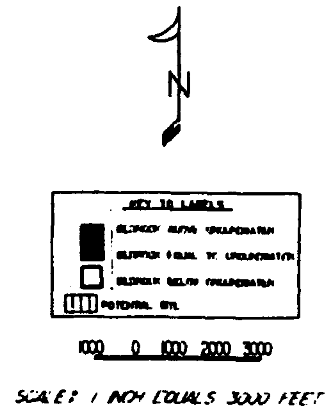
EBASCO
RMA TASK 27
FIGURE 3-16





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ROCKY MOUNTAIN ARSENAL – TASK 27

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DATE

EBASCO	RMA TASK 27	FIGURE 3-16

by comparison is 1,000 feet from a low density population of fewer than 20 people per square mile east of RMA. Site 5 on the western tier is also much closer to the RMA boundary on the groundwater hydraulic gradient compared to Site 6B. This means that any contaminants reaching groundwater would migrate to the RMA boundary more rapidly from Site 5. Because of the proximity to a lower density population and its position on the groundwater gradient, Site 6B was preferred over Site 5. Site 6B therefore was recommended as the backup or overflow site to Site 1B if additional area is needed for facility layout.

No other alternatives or combinations of alternatives would have produced sites achieving as many of the siting criteria as Sites 1B and 6B. The site selection criteria achieved by Alternatives 1B and 6B are shown in Table 3-4.

It should be noted that the groundwater depths under Site 6B are partially based on inferred groundwater contours. Additional site characterization work must be performed if the land disposal alternative is developed further to better define the geohydrologic conditions under Site 6B (see Appendix V.1).

3.8 SITE CHARACTERIZATION

Summary of Specific Sites Suitability

Selection Criteria

The two recommended sites, 1B and 6B, are shown with the criteria that influenced their selection in Figures 3-8 and 3-15. Site 1B satisfied all initial criteria in Table 3-1 except size, which was later determined not to be a problem. Site 6B meets all criteria except for 40 feet depth-to-groundwater. It should be noted that two-thirds of Site 1B (270 acres) are underlain by 50 feet and greater depth to groundwater, which exceeds the initial criterion by 10 feet. Site 6B contains 300 acres of 40 feet and greater depth to groundwater, identified as Alternative 6A in Figure 3-14. These more favorable

TABLE 3-4

SITING CRITERIA ACHIEVED
BY RECOMMENDED ALTERNATIVE SITES 1B AND 6B

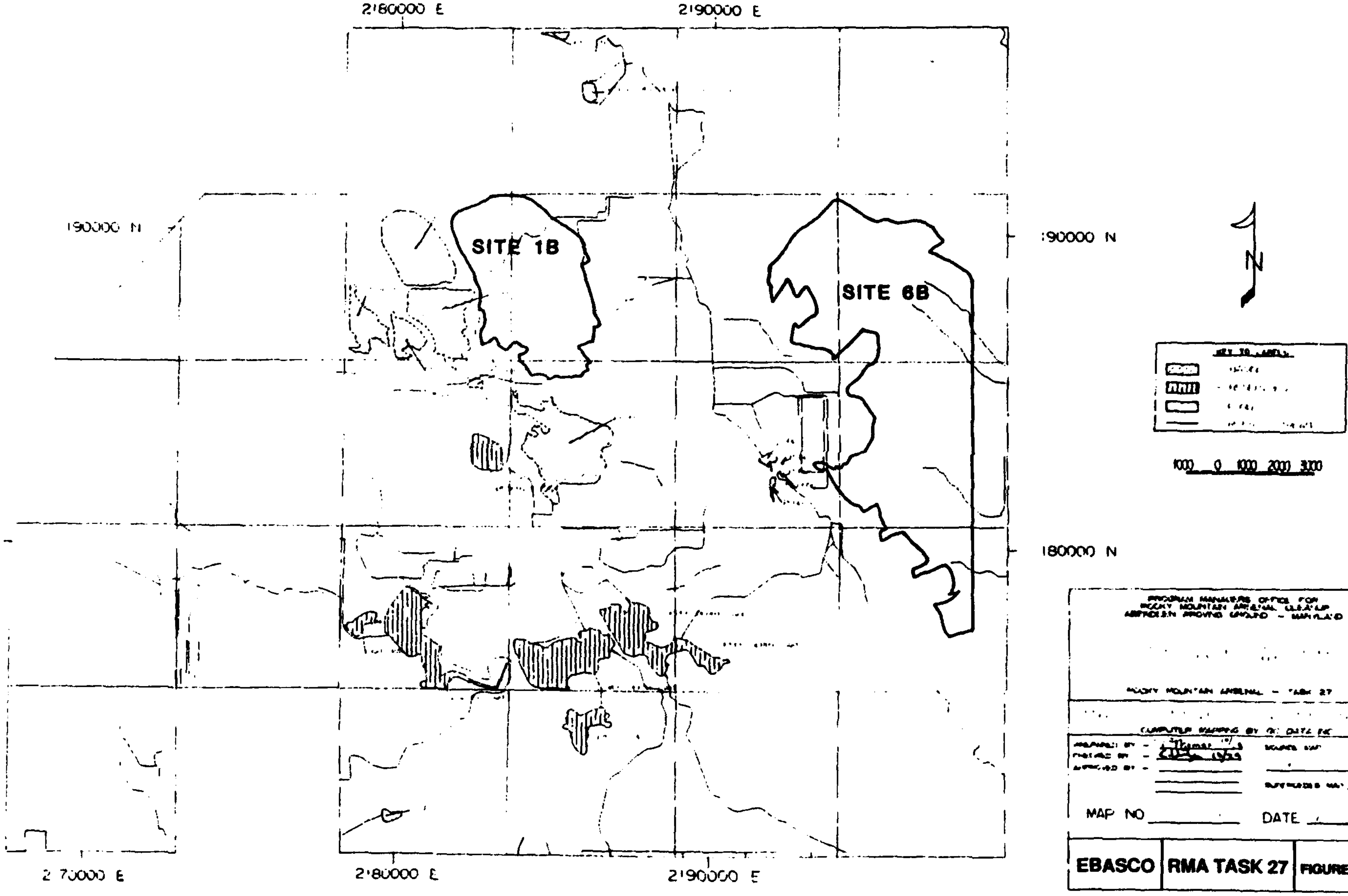
Siting Parameter	Criteria Achieved
Depth-to-groundwater	40 feet for Alternative Site 1B
	30 feet for Alternative Site 6B
Floodplain	No coincidence for either site
Buffer zone	Greater than 1,000 feet from RMA boundary for Alternative Site 1B;
	1,000 feet from RMA boundary for Alternative Site 6B.
Avoidance areas	No coincidence with either site
Saturated alluvium	Both sites are predominantly underlain by unsaturated alluvium
Size	Alternative Site 1B - 400 acres
	Alternative Site 6B - 1,060 acres

areas of greater groundwater depth must be considered in the final facility design. For example, if Site 6B is developed as a land disposal facility, the design layout should use the areas of greater groundwater depth for the disposal of the more hazardous materials. Since the calculated depth to groundwater underlying Site 6B, however, is based on partially inferred groundwater elevation contours, the exact area available must be verified with additional site characterization studies.

<u>Other Values</u>

Figure 3-17 shows the mapped surface water features of both recommended sites and shows no coincidence between major surface water features and the sites. Only minor surface drainages cross either of the sites. Both sites also occur on local topographic highs and on favorable up-slope positions on the northwest trending groundwater hydraulic gradient. The topographic highs are favorable as design features for facilitating the ease of run-on and runoff drainage systems. The relatively high positions on the northwest trending gradient for Sites 1B and 6B are desirable for post-closure concerns in terms of providing a longer time for response action if leachate migration from the facility were to occur. Both sites are a minimum of 1 mile distance from the RMA boundary along the northwest gradient. In addition, the north and northwest groundwater intercept systems would provide additional protection to off-RMA groundwater resources.

Both Sites 1B and 6B are also favorably located relative to existing infrastructure. Existing roads and electrical distribution lines extend to both sites. As discussed above, both sites are favorably located away from existing high density population near the western tier. Both sites are compatible with adjacent existing commercial and industrial uses. Access control measures are included in the facility operation plan and are assumed to remain in place for a reasonable period of time after facility closure (Appendix III).



ROCKY MOUNTAIN ARSENAL - TASK 27

MAP NO

DATE

EBASCO	RMA TASK 27	FIGURE 3-17

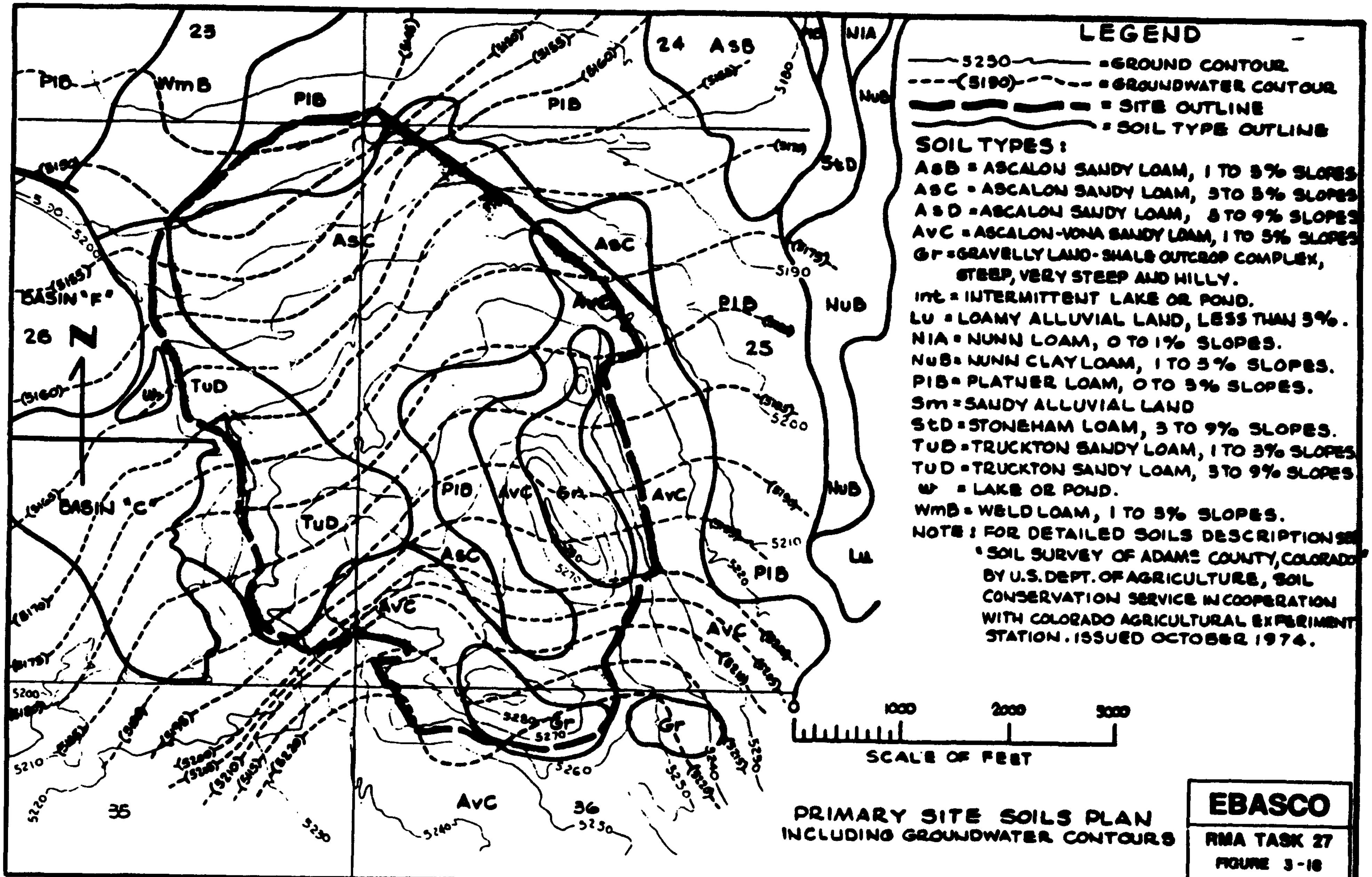
Compatibility of the two recommended sites with existing land uses was considered. The boundaries of Site 1B are immediately adjacent to North Plants buildings but were considered not to impede the remediation of North Plants nor the development of Site 1B for the disposal facility. Site 6B is coincident with suspected unexploded ordnance (UXO) areas that would need to be cleared prior to development. The clearing of UXOs in the area of Site 6B was being investigated, and it was assumed that this factor would not affect the suitability of Site 6B for disposal facility development.

The surface soils of the two sites are sandy silts and silty sands locally identified by the names Ascalon, Platner, and Truckton soils, as described in Appendix I.7 (Sampson & Baber, 1974). Soils maps of the sites are presented as Figure 3-18 and Figure 3-19. In assessing the suitability of these soils for siting a land disposal facility, two soil properties of interest are the available water capacity and the permeability. Low permeability and high available water capacity soils are desirable.

Site 1B is composed primarily of Ascalon soils (moderate permeability, available water capacity 0.11-0.15 in/in), with a smaller but substantial body of Truckton soils on the west side of the site (high permeability, available water capacity 0.05 to 0.12 in/in) and smaller bodies of Platner soils (low permeability, available water capacity 0.14 to 0.18 in/in) and of gravelly land/shale outcrop area.

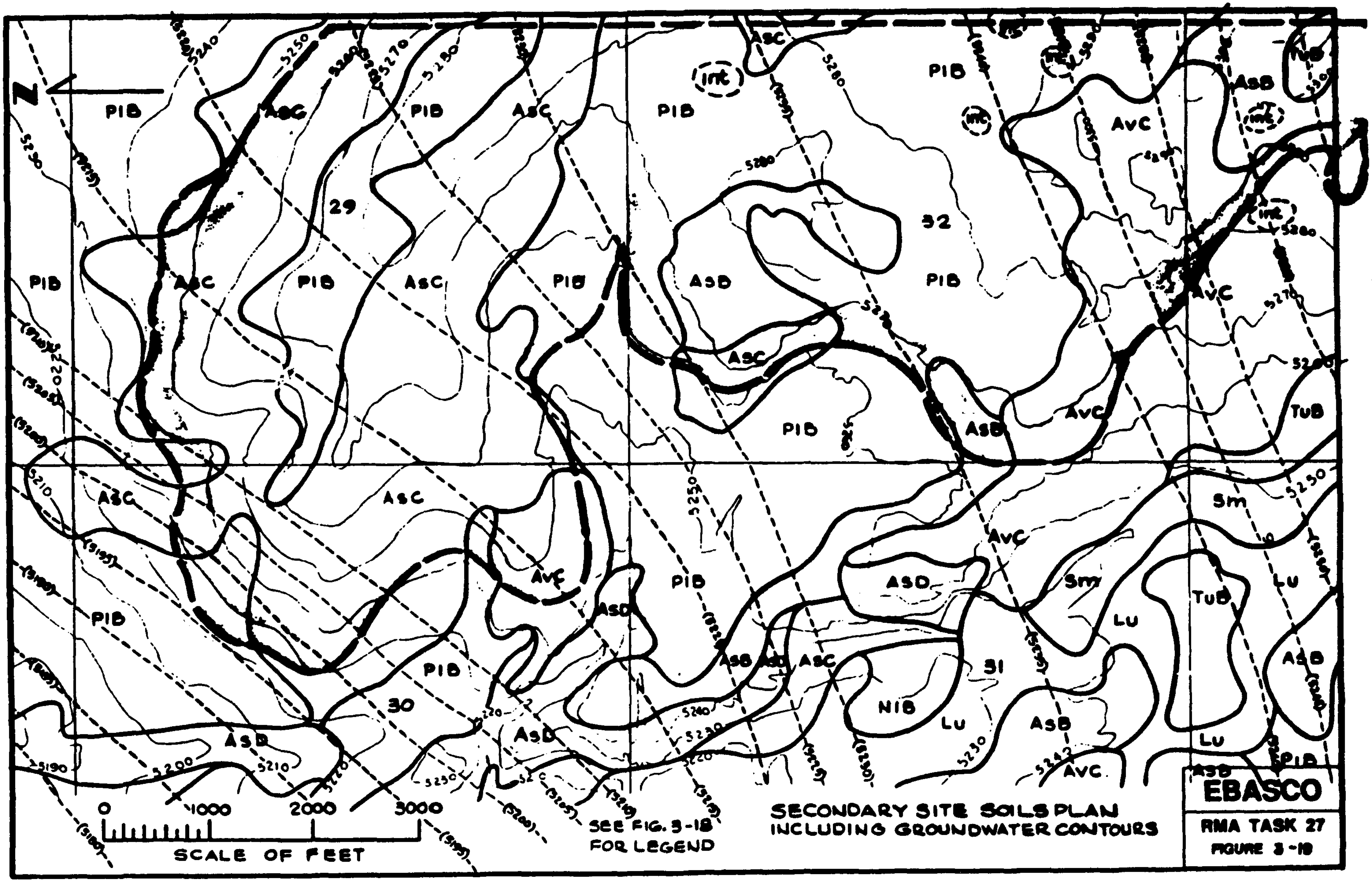
Site 6B consists almost entirely of Ascalon and Platner soils in roughly equal proportions.

The soils of the two sites may therefore be considered in general to be medium permeability soils having an available water capacity of 0.12 in/in. These soils were all considered satisfactory for facility siting purposes. Platner soil was considered the most favorable in the group and Truckton the least favorable.



PRIMARY SITE SOILS PLAN
INCLUDING GROUNDWATER CONTOURS

EBASCO
RMA TASK 27
FIGURE 3-18



SECONDARY SITE SOILS PLAN
INCLUDING GROUNDWATER CONTOURS

RMA TASK 27
FIGURE 3-19

Climatic Suitability

The most favorable characteristic of RMA, as a site for a disposal facility that must be protective for a long period of time, is its climate. The small amount of annual precipitation and high evapotranspiration rate result in a slow rate of migration of leachate through a properly designed disposal facility, as predicted by the HELP model (Schroeder et al., 1984).

A description of the travel time calculations and assumptions used in the HELP model are provided in Chapter 5. The HELP model, when used with EPA-furnished default values of soil properties and other conservative assumptions, generates results indicating a slow but progressive percolation of leachate toward the groundwater table. There is reason to question whether the model is unrealistic in that actually little, if any, groundwater recharge occurs in vegetated areas of RMA (Crabtree & Thompson, 1983).

The latter conclusion was also drawn in a previous surfacewater hydrologic investigation of RMA (Resource Consultants Inc. 1982). In the semi-arid climate at RMA, any rainfall infiltrating the soil is taken up by pasture grasses for transpiration. The referenced report provided a calculation, using the modified Blaney-Criddle method, of monthly consumptive water use for irrigated pasture over 31 years of record. During this period, demands equalled or exceeded precipitation in every month. (When the values were equal it was because both were zero or because the only water available was a rare rainfall occurring outside the irrigation season.)

With respect to major storms, the referenced report postulated that under certain conditions deep percolation would occur, although the consumptive water use calculations in the reference covering the period of record do not support that conclusion.

Considering this analysis, and the observations of the soil survey (Sampson & Baber, 1974) regarding the calcium deposit horizon found at

depths from 7 to 20 inches, it can be seen that the semi-arid climate of RMA is a highly advantageous siting factor when combined with a facility design that provides for a natural vegetated cover. It is unlikely that rainfall on such a cover would penetrate the soil far enough to reach stored waste and generate leachate within the required protective life of the facility.

4.0 DESIGN OBJECTIVES AND CRITERIA

4.1 INTRODUCTION

The three objectives of the design are:

- o Provide waste containment;
- o Prevent contaminant migration; and
- o Confirm facility performance.

To provide waste containment, the disposal facility and individual waste cells must separate the waste from the environment. To prevent contaminant migration, encapsulation of the waste must be achieved. To confirm facility performance, a site monitoring program must be planned, scheduled, and implemented so the effectiveness of the facility can be evaluated and documented.

The design criteria describe, in detail, the features of the facility and the particular requirements they must meet in order to achieve the design objectives. The facility is configured to meet RCRA hazardous waste landfill requirements, which are incorporated in the regulations of the State of Colorado.

As described in Appendix I, any identified hazardous waste found at RMA will very likely be treated prior to disposal. The incorporation of requirements for a RCRA hazardous waste landfill in the design of this facility recognizes that available treatment technologies may not produce a completely innocuous residue. The facility is, therefore, designed to provide protection to the level envisioned in the Colorado Waste Facility Siting Rules, Section 2.5.3, which require that "reasonable assurance is provided that hazardous waste is isolated in the disposal area away from pathways that could expose the public for 1,000 years or some demonstrated shorter period in which the wastes are transformed to an innocuous condition."

The design criteria also reflect consideration of the site selection (Chapter 3) and land disposal concepts (Appendix II) investigations. Chapter 3 describes the geologic and geographic characteristics of RMA based on an examination of the Arsenal for areas best satisfying the siting requirements. Appendix II describes the design features of land disposal facilities, the failure mechanisms to which they are subject, and recent provisions in regulation and practice to cope with failure mechanisms.

Information developed in the preceding chapters and the requirements of the regulations guide the development of the criteria used in the concepts presented in subsequent chapters.

4.2 DESIGN CRITERIA

4.2.1 Provide Waste Containment

4.2.1.1 General Requirements

The waste to be contained is characterized in Appendix I. The waste is estimated to consist of 12.6 million compacted cubic yards (ccy) of contaminated soils, building debris, and treatment residues of heavily contaminated materials. Accordingly it is expected that a facility that could contain 16 million ccy would be adequate. The basic functional element of a facility designed to provide waste containment is the waste cell. The overall facility consists of one or more waste cells, each constructed and functioning independently to contain disposed waste, and common support facilities for maintenance, security, and monitoring. This task includes the evaluation of alternative waste cell concepts including types, number, and configuration of cells.

The primary containment features of a waste cell are a cover and liner, which together completely enclose the waste. The waste cell cover and liner each are a multiple barrier system consisting of some combination of synthetic membranes, natural or manufactured clay layers, drainage layers, and protective soil layers.

The criteria that follow in this section address the recommended features of the waste cell to achieve waste containment. They are not sufficient by themselves to completely establish the design; additional functional requirements will be imposed, as described in Section 4.2.2, which govern critical details of the complete design.

4.2.1.2 Regulations

The regulatory criteria related to design of hazardous waste land disposal facilities are contained in the state of Colorado regulations. Some major provisions of these regulations relating specifically to waste containment include the following:

Colorado Hazardous Waste Regulations/6 CCR 1007-3

- The owner or operator of a landfill must install two or more liners and leachate collection systems above and between such liners (Sec. 265.301).

- Any landfill must have a liner system for all portions of the landfill. The liner system must have a liner that is designed, constructed, and installed to prevent any migration of wastes out of the landfill to adjacent subsurface soil or groundwater or surface water for as long as the waste remains hazardous. The liner must be constructed of materials that prevent wastes from passing through the liner during the active life of the facility (Sec. 264.301).

- The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation (Sec. 264.301).

- The liner must be placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift (Sec. 264.301).

- The liner must be installed to cover all surrounding earth likely to be in contact with the waste or leachate (Sec. 264.301).

- At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to: 1) provide long-term minimization of migration of liquids through the closed landfill; 2) function with minimum maintenance; 3) promote drainage and minimize erosion or abrasion of the cover; 4) accommodate settling and subsidence so that the cover's integrity is maintained; and 5) have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present (Sec. 265.310).

- After final closure, the owner or operator must: 1) maintain the integrity and effectiveness of the final cover, including making repairs to the cover as necessary to correct the effects of settling, subsidence, erosion, or other events; 2) maintain and monitor the groundwater monitoring system; and 3) prevent run-on and runoff from eroding or otherwise damaging the final cover (Sec. 265.310).

State of Colorado Waste Facility Siting Rules/6 CCR 1007-2

- Part 1 Regulations Solid Wastes Disposal Sites and Facilities, Section 4.1.5:

  > Facilities for solid waste disposal shall isolate wastes from the public and environment by emphasizing favorable geologic conditions over engineered improvements of marginal geologic conditions.

- Part 2, Hazardous Waste Landfill Design Criteria Section 2.5.3:

  > Reasonable assurance is provided that hazardous waste is isolated in the disposal area away from pathways that could expose the public for 1,000 years or some demonstrated shorter period in which the wastes are transformed to an innocuous condition.

These design criteria will be reflected in the overall facility design and supporting documents.

4.2.1.3 Containment System

Disposed waste within the waste cell is totally surrounded and enclosed by the containment system. The design of the containment system includes multiple liners forming a physical barrier to solids and having a low permeability to liquids, composed of both synthetic materials and natural clay or soil/bentonite mixture.

The design criteria for the liners include the following (EPA, 1983c; EMCON Associates, 1983):

Item	Requirement
Number of liners and types	Two: One synthetic, one (1) clay/soil-bentonite
Synthetic liners	Nonreactive with waste per standard test methods 100 mil HDPE
Clay/soil-bentonite liner	Minimum 3.0 feet thick with permeability less than 1×10^{-7} cm/sec
Maximum liner slopes	3H:1V when placed in soil
Bottom liner overall slope	Greater than 5 percent
Synthetic liner protection	1.0 foot sandy material free from rocks or debris

The clay or soil-bentonite liner would be placed lowest in the bottom liner system. The synthetic liner would be located nearest the waste with an overlying protective layer of sandy material because it is considered to have the greater resistance to chemical attack. Other layers within the containment system, such as leachate collection and gas detection layers, are described and specified in Section 6.2.2.

4.2.1.4 Cover

The waste cell cover would be designed to reduce water infiltration into the cell, to withstand wind and water erosion, to prevent intrusion by humans, animals, and plants, and to vent any hazardous gas formation. Water infiltration is minimized by run-on control, surface drainage to remove rainfall promptly, surface vegetation to maximize evapotranspiration, and multiple natural and synthetic liners. Water infiltration is drained by integral drainage layers above each liner. Wind and water erosion control are achieved through vegetation and moderate surface slopes.

The surface layer above the uppermost liner would consist of 3 feet of zoned material consisting of topsoil, fill, and armor rock to prevent intrusion damage by small animals, prevent freeze/thaw damage to the liner, and provide a medium that is easily vegetated with native grasses.

The cover must be designed to accommodate any settlement or subsidence within or below the cell while maintaining its integrity and the function of its drainage features. This is achieved by employing flexible materials for cover construction and by controlling waste placement to achieve compaction requirements.

The design criteria used for the cover include (Lutton, 1982; EMCON Associates, 1983):

Item	Requirement
Vegetation	Native grasses
Topsoil	Native soils
Cover Permeability	Equal to or less than bottom liner (for further definition see Section 6.2.2)
Side Slopes	4H:1V
Top Grade	2 to 4 percent

4.2.2 Prevent Contaminant Migration

4.2.2.1 General Requirements

Public health and safety risks are reduced through the prevention of contaminant migration from the disposal site. To achieve this, emphasis is placed on the prevention of leachate formation, hazardous gas generation, and the control of potentially airborne particulates.

Leachate poses a risk to the groundwater aquifers. Gas, through emissions from both surface and subsurface sources, is potentially hazardous to on-site cleanup workers and, in extreme cases, the general public. Dust emissions from site cleanup operations threaten site workers' health or transport contaminants off-site.

4.2.2.2 Regulations

Major provisions of the Federal and state hazardous waste land disposal regulations are designed to meet the general goals of preventing contaminant migration by control of leachate, hazardous gases, and dust emissions. These are specified in the State of Colorado Regulations, 6 CCR 1007-3, as follows:

a. Leachate Control

- o A leachate collection and removal system must be designed, constructed, and maintained just above the liner to collect and remove leachate from the landfill (Sec. 264.301).

- o The leachate depth over the liner must not exceed 1.0 foot (Sec. 264.301).

- o The leachate collection and removal system must be constructed of materials that are chemically resistant to the waste managed in the landfill and the leachate expected to be generated (Sec. 264.301).

- o The owner or operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the landfill during peak discharge from at least a 100-year storm (Sec. 265.302).

- o The owner or operator must design, construct, operate, and maintain a runoff management system to collect and control at least the water volume resulting from a 24-hour, 100-year storm (Sec. 265.302).

b. Hazardous Gas Control

- o The owner or operator must take precautions to prevent accidental ignition or reaction of ignitable or reactive waste. This waste must be separated and protected from sources of ignition or reaction (Sec. 264.17).

- o The owner or operator must take precautions to prevent reactions that produce uncontrolled toxic mists, fumes,

dusts, or gases in sufficient quantities to threaten human health or the environment (Sec. 264.17).

c. Dust Control

- The owner or operator of a landfill containing hazardous waste which is subject to dispersal by wind must cover or otherwise manage the landfill so that wind dispersal of the hazardous waste is controlled (Sec. 265.302).

4.2.2.3 Leachate Control

Water percolating through the wastes in the waste cell forms leachate. Leachate can be produced from rainfall on the exposed waste surface during waste cell construction and waste placement or by water infiltration through the waste cell cover. Leachate control would be accomplished by controlling water infiltration into the waste cell and free water within the waste.

Infiltration would be controlled by the cell cover previously described. The types of water infiltration that must be controlled are surface water infiltration from precipitation or run-on and groundwater infiltration. The cover would be designed to drain surface water off of and away from the waste cells, to remove infiltrated water through evapotranspiration, and to drain infiltrated water through integral drainage layers. Groundwater infiltration would be controlled by locating disposal cells above maximum groundwater levels. Stormwater run-on would be controlled through site grading and drainage system design.

Prevention of free water within the waste cell at the time of construction would be accomplished by controlling the water content of the waste as it is placed within the cells. Wastes containing free water would not be placed within the cells.

In order to monitor and promote the effectiveness of the containment system, the waste cells would contain a leachate collection and detection system. The collection system prevents accumulation of the liquid through the use of an internal drainage system. Liquid would be drained through drainage laterals by gravity for removal and treatment. Below the synthetic liner, piping would be used as a detection system. Any leachate found in the detection system piping signifies a breach in the liner.

The required demonstration that the facility can protect the public for up to 1,000 years hinges primarily on protection of groundwater from leachate contamination. This demonstration is dependent on an integrated analysis of site climatological, geological, and hydrological factors and the facility design to identify pathways and leachate travel time and quantity.

The Hydrologic Evaluation of Landfill Performance (HELP) computer program (Schroeder et al., 1984) is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model accepts climatologic, soil, and design data and utilizes a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. Land disposal systems including various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils, as well as synthetic membrane covers and liners, may be modeled. The program was developed by the EPA to facilitate rapid estimation of the amounts of runoff, drainage, and leachate that may be expected to result from the operation of a wide variety of landfill designs. The model, applicable to open, partially closed, and fully closed sites, is a tool for both designers and permit writers. The HELP model is applicable to most land disposal applications, but was developed specifically to perform hazardous waste treatment and disposal facility evaluations as required by the Resource Conservation and Recovery Act. This model is used in

Chapter 5 to demonstrate that the facility design is protective of human health and the environment, taking into account only the time required for leachate to reach groundwater beneath the facility and taking no credit for dilution or degradation of contaminants, time to travel laterally off-site, nor groundwater treatment systems such as those in present use.

The design criteria used for the leachate collection and detection system include (EMCON Associates, 1983; Schroeder et al., 1984):

Item	Requirement
Synthetic liner arrangement	Sawtooth pattern
Leachate collection lateral slope	2 to 4 percent
Leachate collection main line slope	Greater than 0.5 percent
Pipe material	HDPE for cap systems. Vitrified clay for bottom liner systems
Pipe diameter	6.0 inches
Maximum lateral spacing	50 feet
Maximum allowable head on liner	1.0 foot
Climatologic and soil data	Default data for Denver, Colorado internal to the HELP Model - Years 1974-1978

4.2.2.4 Hazardous Gas Control

Controlling hazardous gas formation is the primary method of preventing gas emissions. This is accomplished through waste control, whereby waste-to-waste incompatibilities are eliminated and uncontrolled decomposition is minimized. Proper waste control prevents mingling of incompatible wastes which can react chemically to generate hazardous gases. Waste cells incorporate a gas collection and venting layer which collects any gas that forms within the waste cell. The gas control system would either vent and disperse nonhazardous gases or collect any hazardous gases for later treatment.

Hazardous gas generation is expected to be minimal based on expected contaminant concentrations and proper waste control. Some solidification processes, if used in conjunction with land disposal, can emit ammonia, while other waste degradation reactions can produce CH_4, H_2S, or other hazardous gases. Venting or gas treatment would be provided for every waste cell. Gas would be monitored to ensure compliance with public health, safety, and environmental regulations.

The design criteria include (EMCON Associates, 1983):

Item	Requirement
System	Permeable venting layer
Material	Coarse sand
Placement	Layer directly over waste
Thickness	1.0 foot
Venting	Atmospheric

4.2.2.5 Dust Control

Contaminated dust particles can be either blown off-site by wind or by attaching to larger objects that are transported off-site by some means other than wind. Dust controls can mitigate dust emissions from disposal operations and wind erosion. The design components necessary to meet this design objective are construction vehicle cleaning, haul road paving and cleaning, waste control, waste cell cover design, and gas control. Waste control includes the regulation of waste moisture content which minimizes dust potential. The waste cell cap is a primary barrier to the migration of potentially contaminated dust after waste placement and site closure.

The dust emissions from land disposal facility construction and operation would be controlled below Colorado Air Quality Control Regulations and Ambient Air Quality Standards. This would be accomplished by dust suppression operations such as keeping facility working faces to a minimum and dust suppression.

The design criteria include (EMCON Associates 1983):

Item	Requirement
Dust control	Pave major haul roads
	Minimize working areas
	Water spraying
	Dust suppression chemical application
	No waste placement in winds greater than 35 mph
	Clean construction vehicles

4.2.3 Confirm Facility Performance

4.2.3.1 General Requirements

The requirements relating to the confirmation of the facility performance are monitoring, construction QA/QC, and closure/post-closure care. These features include such items as the monitoring of observation wells around the facility, monitoring of leachate collection and detection systems, and the inspection of the physical plant features. Monitoring facilities which are part of the physical design are described here. QA/Q/C and closure/post-closure care provisions are described in Appendix III.

4.2.3.2 Regulations

The compliance period is the period of time from initiation of the hazardous waste landfill construction to as much as 30 years after closure activities are completed. The compliance period includes monitoring and inspection activities as described in the Colorado Hazardous Waste Regulations 6 CCR 1007-3. These activities entail groundwater monitoring; inspection of liners and cover systems for uniformity, damage, or imperfections; and weekly inspection of operation for deterioration or malfunction of run-on and runoff control

systems, for proper functioning of wind erosion control and for the presence of liquid in leak detection systems.

4.2.4 Final Design Criteria

The preceding sections define the criteria used in the concept assessment performed for this task. If a land disposal facility is constructed at RMA, the final design of the facility will require criteria addressing detailed design considerations such as materials and installation specifications, which are beyond the scope of this assessment.

4.3 SUMMARY

The design objectives and criteria presented are directed toward meeting the overall goal of protecting public health and safety by achieving a facility design which satisfies the regulations and contributes to the alternatives assessment of the feasibility study under CERCLA. The three design objectives formulated to meet the goals are: provide waste containment; prevent contaminant generation and migration; and confirm facility performance.

The design objectives and criteria direct the concept facility and waste cell assessment by focusing on the primary objectives. The features of the facility and their operational functions include: multiple barrier systems to provide waste containment; leachate control, hazardous gas control, and dust control to prevent contaminant generation and migration; and the confirmation of facility performance through the use of monitoring wells located throughout the land disposal facility.

Chapters 5 and 6 provide the details of the concept developed to meet the design objectives and criteria.

5.0 WASTE CELL CONCEPTS

5.1 SCREENING OF WASTE CELL CONCEPTS

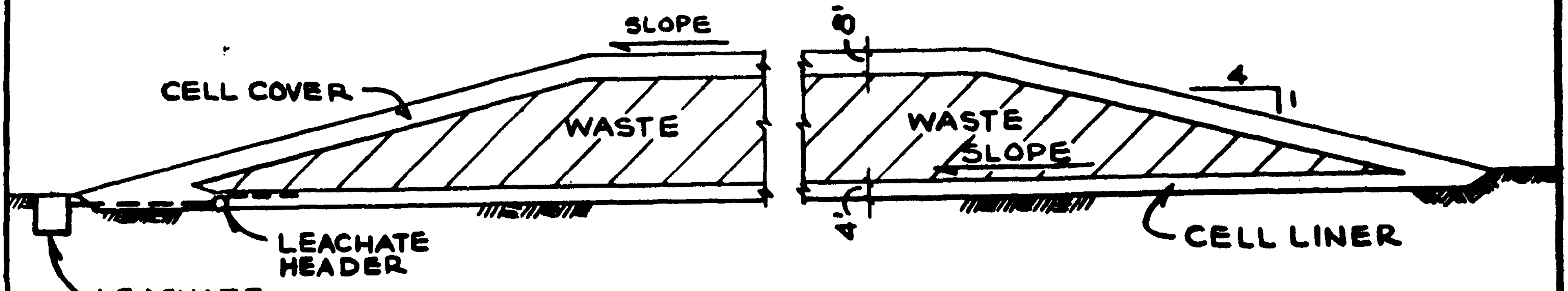
Many designs have been developed for disposal facilities for hazardous, solid, and radioactive waste. The main objective for all designs is long-term containment. Many of the designs used for containment of such waste rely primarily on geologic barriers for long-term isolation. As discussed in Section 3.8, RMA's outstanding natural barrier is climatological rather than geological. In order to utilize the climatological barrier effectively, special attention must be given to the surface features of the facility: the waste cell cover and run-on/runoff control, maintenance of vegetation, and prevention of erosion or intrusion damage.

The following paragraphs describe several current waste cell design concepts that might be applied at RMA and the screening process that resulted in the selection of one concept for further development within this assessment.

Three designs for hazardous waste facilities are judged applicable to RMA. The designs, termed the A, B, and C concepts, are an above-ground earth cell design, a below-ground earth cell design, and a below-ground concrete vault, respectively. The B and C concepts, although termed below-ground designs, actually rest on the existing ground surface and are backfilled to obtain the equivalent of a below-ground design.

A Concept

The A concept, shown in Figure 5-1, is based on the arrangement used in the previous concept design (IT Corporation, 1984). The IT design uses an above-ground 100,000 cy cell with a 25 foot waste height. The height of the IT Corporation cell was the result of a width restriction that was imposed so the cell could be covered with a building.



TYPICAL CROSS SECTION
ABOVE GROUND WASTECELL
CONCEPT - A

EBASCO
RMA TASK 27
FIGURE 5-1

Several modifications to the IT Corporation design were made in this assessment to improve its efficiency without sacrificing its integrity. They include:

(a) Elimination of the benches at the cell half height.

Removal of the cell benches was based on limiting soil loss to acceptable levels as calculated by the Universal Soil Loss Equation.

(b) Removal of the width restriction.

The width of the IT Corporation cell was limited to 250 foot so a temporary cover could be placed over the cell.

Advantages of using a temporary cover are prevention of leachate formation due to rainfall on the wastes, minimization of wind blown dust, and providing a controlled environment for cell construction. Since the proposed land disposal facility is to be built in a semi-arid environment, the need for temporary cover was scrutinized. The Denver area averages 15 inches of rainfall a year with a 28-inch net annual average evaporation deficit. Five months of the year average less than an inch of rain each month and the three peak rainfall months average 2 inches per month. These figures suggest that saturation of exposed fill surfaces with consequent leachate runoff would be a very rare occurrence. Also, there are methods of preventing the formation of leachate without the expense of covering the entire cell, such as tilling the wetted surface to mix free water into the dry soil below.

The primary source of dust emission comes from haul roads and not waste placement activities at the cell; therefore, a temporary cell cover will have little effect on curbing dust emissions. The primary way to minimize dust emissions is to

have an aggressive dust control plan using water and dust suppression compounds.

(c) Addition of a barrier to prevent burrowing animals from penetrating the cell.

A rip rap rock barrier is used in the cover to minimize the intrusion of plants and animals into the cover drainage layer to give the cover long-term integrity. This will prevent the tilling or mixing of the soil zones and consequent loss of effectiveness of the drainage layer caused by prolonged activity of burrowing animals.

<u>B Concept</u>

The B concept shown in Figure 5-2 is similar in design to the A concept but is constructed within earthen berms to improve cost efficiency. Use of berms can increase a cell's volume while only minimally increasing the amount of construction materials.

Inherent advantages of the B concept are:

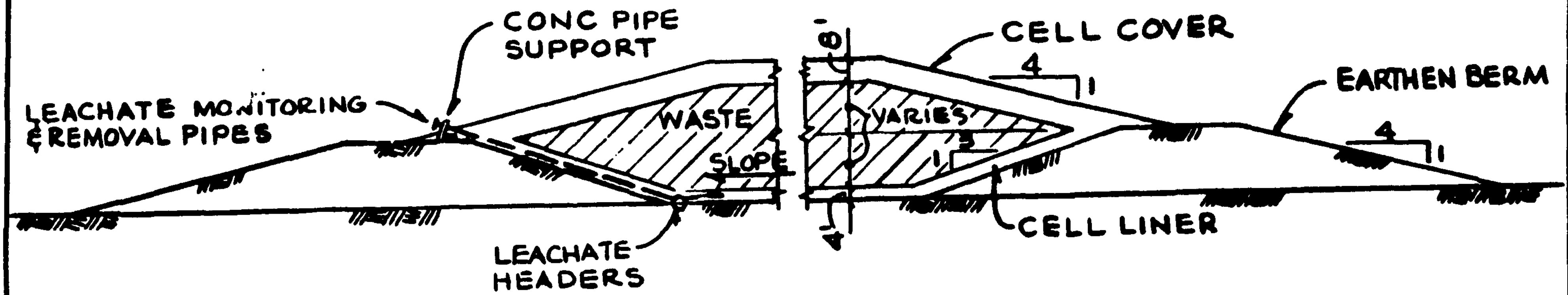
- Cells will create less noticeable topographic relief;

- The berms provide wind protection to the lower half of the cell thereby reducing fugitive dust emissions; and.

- Waste cells can be constructed side by side sharing berms that reduces construction costs.

<u>C Concept</u>

The C concept depicted in Figure 5-3 is a vault design that has been used for low-level radioactive waste. A concrete cover and liner are not used because cracks that normally develop in large soil-supported concrete slabs, due to differential soil settlement, can allow water to



TYPICAL CROSS SECTION
ABOVE GROUND WASTE CELL
CONCEPT-B

EBASCO

RMA TASK 27

FIGURE 5-2

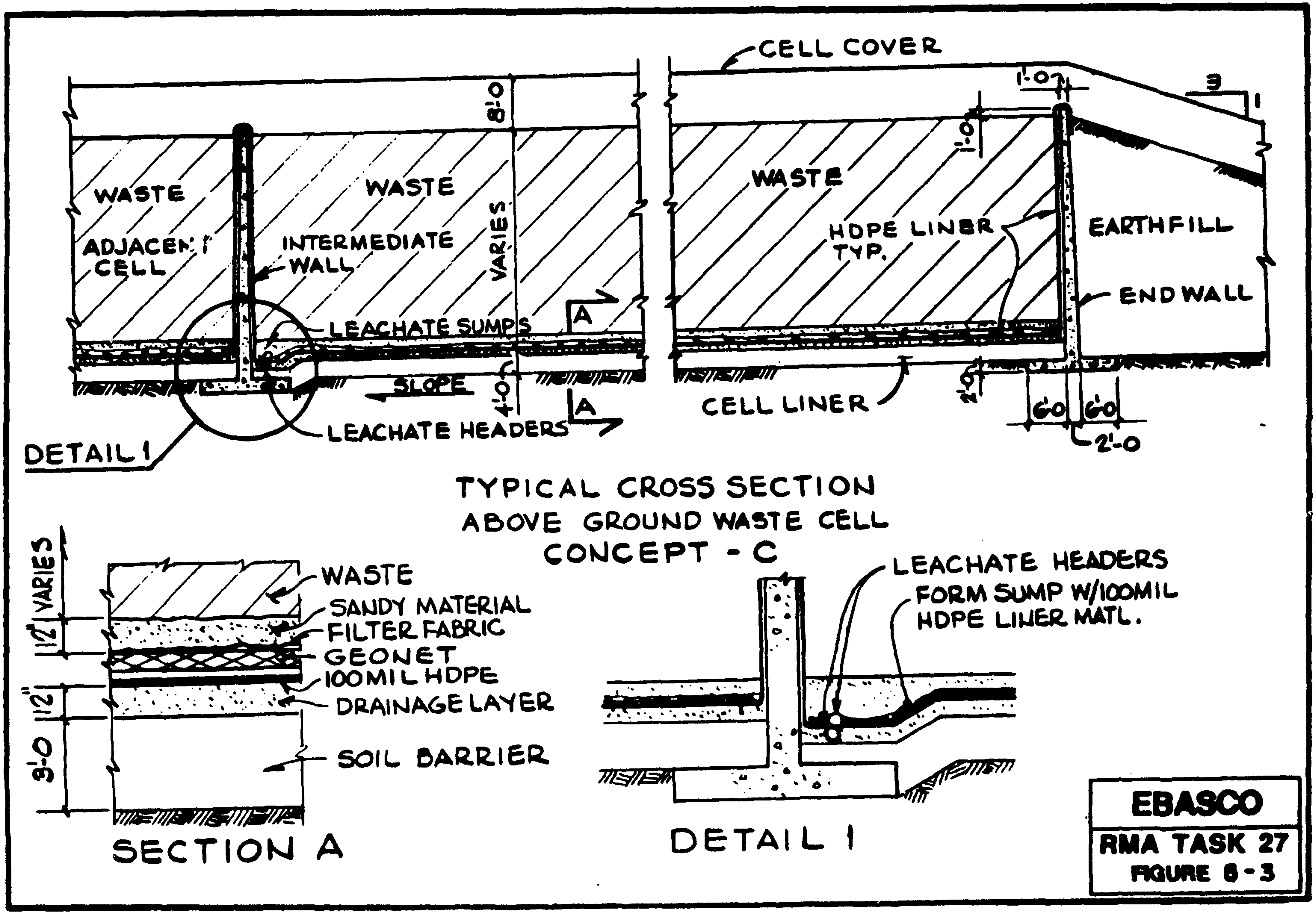

CELL COVER
3
1
1'-0
1'-0
8'-0
WASTE
ADJACENT CELL
WASTE
INTERMEDIATE WALL
VARIES
LEACHATE SUMPS
A
SLOPE
4'-0
A
LEACHATE HEADERS
DETAIL 1
WASTE
HDPE LINER TYP.
EARTHFILL
END WALL
CELL LINER
2'-0
6'-0
6'-0
2'-0
TYPICAL CROSS SECTION
ABOVE GROUND WASTE CELL
CONCEPT - C
VARIES
12"
12"
3'-0
WASTE
SANDY MATERIAL
FILTER FABRIC
GEONET
100 MIL HDPE
DRAINAGE LAYER
SOIL BARRIER
SECTION A
LEACHATE HEADERS
FORM SUMP W/100MIL
HDPE LINER MATL.
DETAIL 1
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FIGURE 8-3

percolate through the cell. As a result of this consideration, the C concept includes the same cover and liner system as the A and B concepts.

Layout studies of the C concept demonstrated that cells could be built economically in groups of four. Larger configurations of cells were determined to be unattractive because of the difficulty in routing surface runoff away from cells.

The major advantage of the C concept is its efficient use of liner. In plan view, it has the highest volume of waste per square foot of bottom liner. This offsets the added cost of concrete retaining walls. The economy of the design is further improved when built in blocks of four because interior walls are shared between cells.

The preliminary cost estimate prepared for the C concept is based on using reinforced bearing walls, although less expensive alternatives were evaluated. The advantage of using a bearing wall design is ease of replacing damaged cells. It is possible to use nonbearing side walls but that arrangement poses operation problems. During excavation of a damaged cell, nonbearing walls require bracing to be used during excavation to keep cell walls from collapsing inward. Otherwise the soil levels on both sides of the wall must be lowered at the same rate, which requires adjacent cells to also be excavated to repair a damaged cell.

Another option investigated is reinforced earth retaining walls. Reinforced earth retaining walls have long been used by the highway industry on highwalls and steep embankments. The principle of earth retaining walls is that soil anchors are tied to the wall at set heights. The soil anchors mobilize passive soil pressure to help support the wall. Retaining walls of this type are available in modular blocks, which are stacked, using a minimum of time and effort. This concept was not pursued because it presented layout problems for multiple cells.

5.2 SELECTION OF THE RECOMMENDED CELL CONCEPT

Two steps were used to arrive at the recommended cell concept design. First, the geometric considerations of cell design were evaluated. This included an evaluation of land area requirements for the different concepts and optimum cell proportions. The word "optimum" is used loosely because a cell can only be optimized within preset constraints, for example, an upper limit on height. Secondly, an economic comparison was made between the three concepts at various cell sizes.

As discussed in Chapter 3 - Site Selection, primary and secondary sites were selected for the concept design of the land disposal facility. The primary and secondary sites are approximately 400 and 1,000 acres in size, respectively.

Figure 5-4 shows area requirements for the three concepts as cell sizes vary. Area requirements were based on a square cell with a 35 foot waste height. A square cell dimension was chosen because it represents the largest area that can be enclosed given a set perimeter length, excluding a circular shape, which was considered uneconomical to build. A 35 foot waste height was chosen for comparison purposes because it is the height that a 100,000 cy cell (the smallest size that would be evaluated) would be if a facility consisting of such cells were laid out on a 1,000 acre site and sized to contain 16 million cy of waste. A facility consisting of 100,000 cy cells would occupy the most area, and a 1,000 acre site was the largest single site area identified in the site selection process. Figure 5-5 illustrates the effect on cost per cubic yard of waste for waste cell construction, as the cell size (length of a side of a square cell) and waste height are varied. The cost is the ordinate and the waste height is the abscissa; each curve in the family of curves represents one of the following cell side lengths: 500, 1,000, 1,500, and 2,000 foot, as indicated by the curve symbol and the key at the bottom of the figure. Figure 5-5 shows that

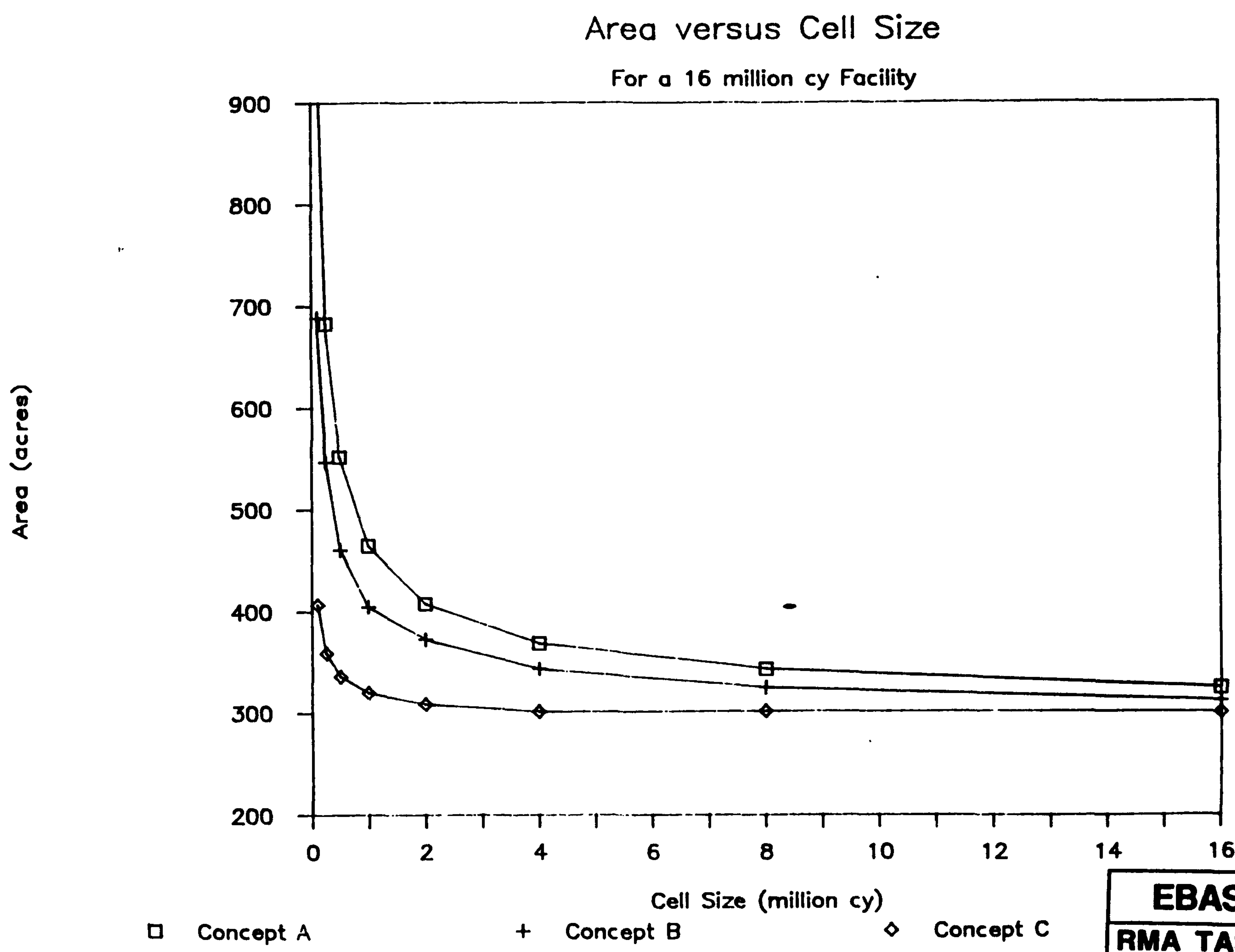

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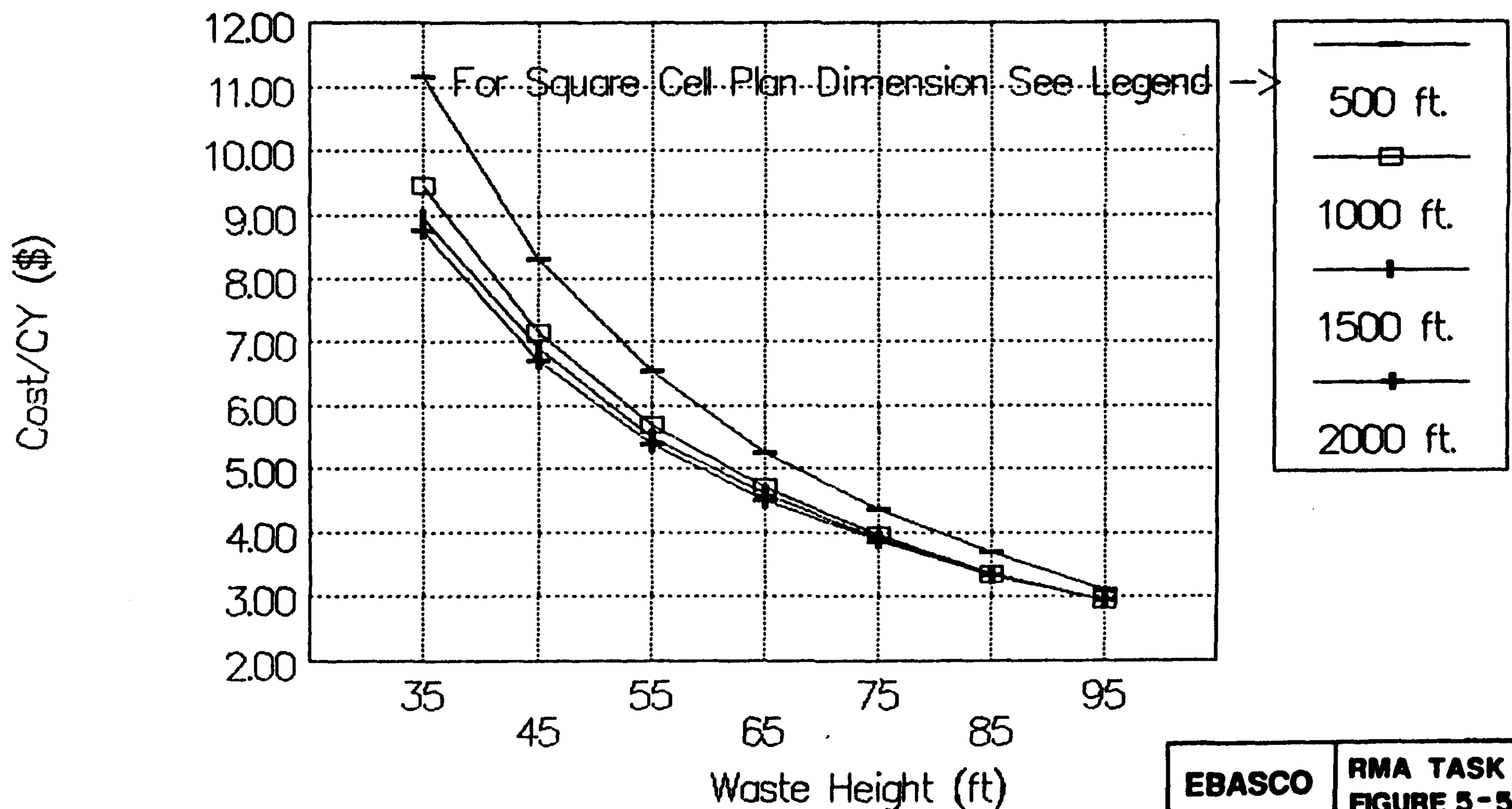
FIGURE 5-4

Rocky Mountain Arsenal – Task 27

Cost/CY vs Waste Height



EBASCO	RMA TASK 27 FIGURE 5-5

there is a cost penalty in cell construction for low waste height cells compared to higher waste height cells. This is because a low cell has a larger surface area for a given waste volume than a higher cell. The economic advantages of higher cells are explored further in Chapter 6. For the remainder of this chapter, only 35 foot high cells are discussed.

The purpose of the screening process is to select a cell concept for the layout and design of a facility. The cell concept selection process will not determine cell size because that will depend on a number of factors, such as buildout period and waste volume. To assist in the selection process, a screening cost estimate was made comparing construction costs for the three concepts.

The screening was based on costs for the disposal of 16 million cy of waste using various cell sizes. Costs associated with placing the waste material in the cell and the cost of supporting facilities were not included in the estimate. The same cover and liner systems were used for all three concepts, and the B and C concepts include the cost of berming materials around the cells.

Results of the screening cost estimate are presented in Figure 5-6. The B concept is the lowest cost alternative in all cell size ranges. The cost curve for the B concept flattens out rapidly for cell sizes larger than a 1 million cy.

The A and B concepts are very similar in cost throughout the entire range of cell sizes evaluated. The cost curve for the A and C concepts begins to flatten out for cell sizes larger than 2 million cy.

Based on the screening cost estimate, the B concept is clearly the economical choice for cells less than 1 million cy. For cell sizes larger than 4 million cy, the cost differential between concepts is approximately a 20 percent difference between the B and C concepts and a 5 percent difference between the B and A concepts.

Construction Costs versus Cell Size

For a 16 million cy Facility

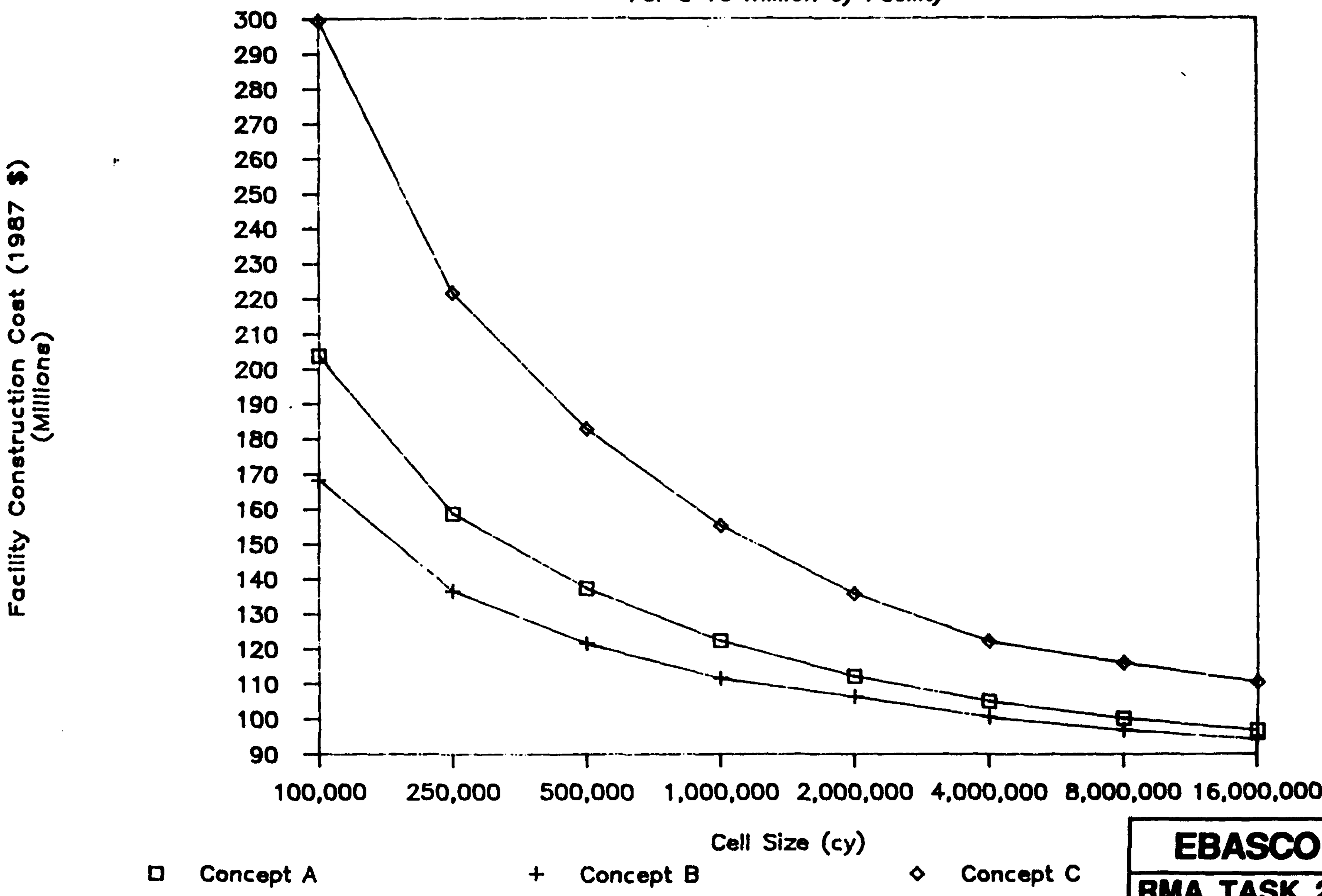


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FIGURE 5-6

Considering both the geometric and economic aspects, the B concept is used for further investigation in Facility Configuration, Chapter 6. The B concept is clearly more efficient at smaller cell sizes; present state-of-the-art hazardous waste landfill designs have not exceeded cell sizes larger than a half million cy. (See Appendix II, Table II-2.)

5.3 SELECTION OF CELL CONSTRUCTION MATERIAL

A hazardous waste landfill is composed of a cover and liner system. The cover system is composed of a cover layer, lateral drainage layer, synthetic liner, soil barrier, and a gas collection layer. The liner system is similar in construction to the cover system except that it has no cover or gas collection layers. For discussion purposes, the cover layer is meant to refer to the outermost layer on the cover system that is exposed to the environment.

5.3.1 Cell Cover Layers

The functions of the cover layer are to maximize surface water run off, minimize infiltration, and protect underlying layers. The effectiveness of the cover layer is dependent on its slope and physical properties. The importance of the slope is to provide good surface water drainage, thus avoiding ponding. A 3 to 5 percent slope has been recommended for drainage purposes, as discussed in Chapter 4. A number of materials have been used for cell covers: soil, rip rap, concrete, asphalt, and soil cement. The physical properties of these materials are discussed below and a recommendation is made at the end of this section regarding the most suitable cover material.

Soil is a commonly used cover material. It is inexpensive, provides excellent freeze-thaw protection, and is self healing if damaged. Water erosion is an important design limitation of using soil as a cover material. If left uncontrolled, water erosion can quickly destroy the integrity of a cover. Water erosion can effectively be controlled by establishment of a vegetative layer on the cover and by limiting the length of overland flow with collection channels.

Rip rap has some distinct advantages over other cover materials. It is durable, erosion resistant, and offers protection from animal intrusion to underlying layers. A disadvantage of this material is its high permeability and cost. The rip rap's permeability can be greatly lowered by filling its void spaces with soil.

Concrete, asphalts, and soil cement can all form acceptable caps, although they are more expensive than soil and require maintenance. Since the intent is to require no maintenance on the cap after the 30-year post-closure period, these alternatives were excluded from further consideration. For design purposes, a soil cover layer with vegetation is recommended. Afooter establishment of the vegetation layer, the cover should provide a durable nonerosive surface.

5.3.2 Lateral Drainage Layers

The function of lateral drainage layers is to minimize the downward percolation of water. Lateral drainage layers provide a high permeability channel for water to move laterally to the perimeter of the cell instead of percolating downward.

Typically, lateral drainage layers are composed of sand and gravel. Recently, plastic materials (geonets) have been introduced to replace granular materials. Geonets are fabricated by crisscrossing strips of plastic into sheets that are approximately 1/2 inch thick. This material affords the same transmissivity (the ability to transmit water) as a 1 foot thick sand drainage layer.

Geonets offer distinct advantages over granular materials. Geonets can be installed using a minimum of time and equipment, since they only need to be rolled out on a smooth surface. Under certain applications, a geonet is covered with a filter fabric to prevent soil particles from clogging its drainage channels.

Regardless of the material used for lateral drainage layers, collection pipes must be used to move leachate and stormwater from the drainage layers to the collection sumps. Design and spacing of the collection pipes is an important factor influencing the percolation rates from the base of the cover and liner systems.

Several layouts can be used for leachate collection pipes as shown in Figure 5-7. The designs are presented in the order of the longest travel distance of leachate to collection pipes. Case 1 is the simplest of the designs but, in the cell corners, leachate must travel 849 foot before reaching a collection pipe. This is undesirable because it could take months or even years to detect a small leak. Another undesirable feature of the design is the location of the collection sump in the center of the cell, which is usually the deepest part of the cell and, therefore, the furthest from surface access.

Case 2 is a better design in which the longest flow distance to a collection pipe is 600 foot, and collection sumps are located at cell corners. The fish bone design of Case 3 provides for shorter flow distances to collection pipes (approximately 300 foot), with only a minimal increase in materials. A problem with the fish bone design is cleaning plugged lines located on branch laterals.

The sawtooth design of Case 4 is an efficient design, having short flow distances (approximately 100 foot), with none of the deficiencies noted in Cases 1 through 3. The disadvantage of the design is that it requires the cell base to be graded to a complex slope pattern. The grid design of Case 5 offers approximately the same drainage efficiency as Case 4 but is less efficient economically since it uses more materials. The advantage of the design is that it can be laid out on a flat grade.

The sawtooth design (Case 4) is recommended for design purposes because it best fits the topography of RMA. The Case 4 design can be laid out on a 1.5 percent slope with the sawteeth sloping 3 percent

COLLECTION PIPE NETWORK LAYOUT

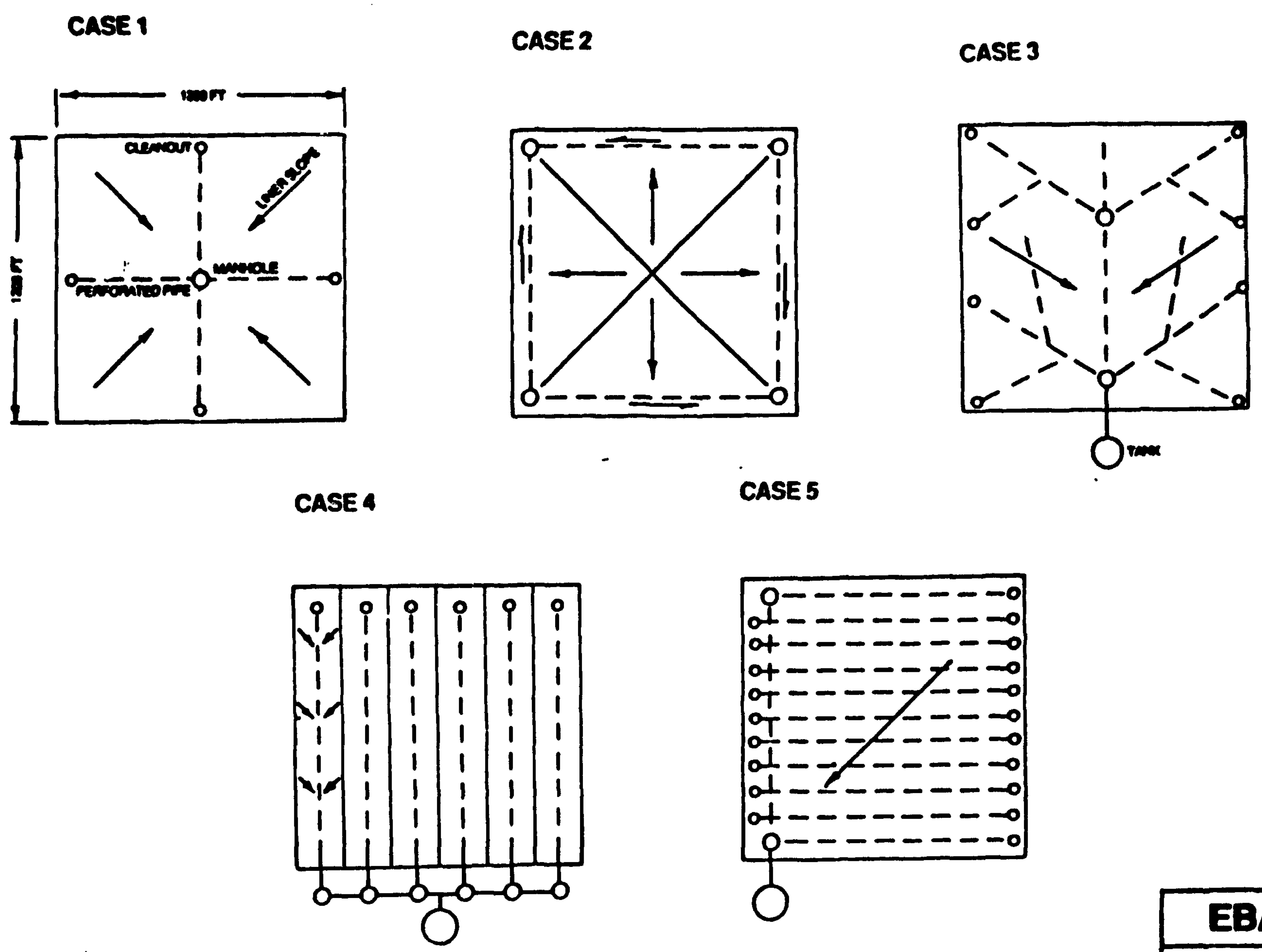

FIGURE COURTESY OF UNIVERSITY OF WISCONSIN, LANDFILL DESIGN MANUAL, 1987

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FIGURE 5-7

to the collection pipes. The Case 5 design requires a 3 percent overall slope. Since the topographic slope of the RMA sites is about 1.5 percent, Case 4 allows constant height waste calls for minimum earthwork while achieving the desirable 3 percent drainage slope. Selection of the sawtooth is further supported by earthwork calculations that show less than a 2 percent slope is available for construction of grades on the primary and secondary disposal sites.

5.3.3 Soil Barriers

Soil barriers are commonly constructed from natural clays or soils amended with bentonite or other admixtures. Preferably, soil barriers will be constructed of clay materials located either on-site or at a nearby location. Only if clay materials are not locally available at a reasonable price would other alternatives be selected.

Current geologic information from Phase I borings suggests no large high quality clay deposits are present at RMA. A report investigating potential on-site and off-site sources of clay found there was insufficient information to support the assumption of an on-site source of clay (Martin 1986). The report identified two possible off-site sources of clay, a mine 25 miles from Denver used for brick manufacturing and a bentonite supplier in Wyoming (American Colloid). The material used for bricks was rejected from further consideration because it has a low clay content and may not meet the acceptable hydraulic conductivity requirements.

Typically, bentonite alone is not used to construct soil barriers but is mixed with native soil in an appropriate ratio to obtain a soil having a permeability of less than 10^{-7} cm/sec. A typical ratio for a soil bentonite mixture is 5 to 7 percent bentonite per unit weight of soil. The soils are mixed using one of two methods: a land area method where mixing occurs in a pit using a rototiller-type machine or a conventional pug mill operation. The pug mill is the more expensive of the two but has the advantage of providing high quality control of the product.

Relatively impermeable soil barriers can also be constructed by the addition of pozzolanic materials (fly ash) to a soil. Pozzolans reduce permeability through a cementing action of the soil particles. A problem with pozzolans is that the cementing of the soil particles can be destroyed by acids or other chemicals (e.g., sulfates). Soil admixtures other than bentonite were rejected from further consideration because leachate from the disposal facility is expected to contain organic chemicals whose effect on the amended soil is unknown, and bentonite is believed to be less susceptible to organic chemical attack than alternate materials such as cements and polymers.

For the purposes of this task, soil barriers are assumed to be constructed from a soil amended with bentonite. This method was chosen because it is thought to be the most assured means by which a large volume of material could be supplied in the absence of a proven source of low-permeability clay and the uncertainty regarding chemical resistance of other additive materials.

For cost estimating purposes, soil barriers were priced using bentonite supplied from Wyoming. A pug mill operation was assumed for mixing.

5.3.4 Flexible Membrane Liners

As discussed in the design criteria, at least one flexible membrane liner (FML) is required in both the cover and liner systems. As mentioned in Chapter 3, an important requirement for FML selection is chemical compatibility with the leachate. Four commonly used liner materials are high density polyethylene (HDPE), chlorinated polyethylene (CPE), chlorosulfonated polyethylene (CSPE), often referred to as Hypalon, and polyvinyl chloride (PVC). Table 5-1 presents a summary of liner chemical compatibilities and other physical properties of those liner materials.

Review of Table 5-1 shows that HDPE is compatible with most of the chemical groups. Use of HDPE is further supported by a review of recently permitted hazardous waste facilities such as the U.S.

TABLE 5-1
FLEXIBLE MEMBRANE LINER COMPATIBILITY *

		HDPE	CPE	CSPE	PVC
Low temperature resistance	-20°				o
	-40°		o	o	
	-60°	o			
	-80°	o			
High temperature resistance	+150°	o	o	o	
	+200°				
Field seaming method		E F	A	A	A
Good UV resistance		o	o	o	
General Chemical resistance at 158°F:					
Aliphatic hydrocarbons		o	o		
Aromatic hydrocarbons		o			
Chlorinated solvents					
Oxygenated solvents		o			
Crude petroleum products		o	o		o
Alcohols		o	o		o
Acids		o	o		o
Bases		o	o		o
Heavy metals		o	o		o
Salts		o	o		o

O = Good resistance (General).
Blank = material is incompatible with waste
All temperatures in degrees fahrenheit.
Field seaming method: Adhesive.
A = Adhesion E = Extrusion F = Fusion
* Table courtesy of Poly-Flex Corporation

HPDE: High density polyethylene
CPE: Chlorinated polyethylene
CSPE: Chlorosulfonated polyethylene
PVC: Polyvinyl chloride

Pollution Control, Inc. facility at Grassy Mountain, Utah, and at Browning-Ferris Industries' facility at Last Chance, Colorado, both of which selected this material for their liner systems.

5.3.5 Gas Collection System

Gas is produced in a hazardous waste land disposal facility from both chemical reactions and the decomposition of organic wastes. Sanitary landfill wastes typically produce a gas mixture composed of equal parts of carbon dioxide and methane. Gases produced from chemical reactions are dependent on the composition of the chemical wastes. Gas production from chemical reactions can be limited by effectively separating reactive wastes during placement.

Any gas produced must be vented to avoid a buildup of internal pressure which can damage the integrity of the cell; gas collection systems are typically installed in the cover system of landfills for this reason. Selection of a gas collection system is guided by the quantity of gas produced and the disposal or treatment technology used for the collected gas.

A relatively simple gas collection system is recommended for the RMA disposal facility. Gas production rates are expected to be low due to the low organic content of the waste material. Also, wastes will be segregated to avoid gas producing reactions.

An effective gas collection system suitable for use at RMA consists of a perforated pipe along the top of the waste layer. The perforated pipe is bedded in a crushed rock layer and wrapped in filter fabric to avoid clogging with fines. Spacing of the collection pipes will depend on the amount of gas to be vented.

5.4 SELECTION OF CELL COMPONENTS

5.4.1 Selection of Cover System

Factors influencing the design of hazardous waste disposal facilities include regional precipitation and evaporation, soil properties, and the efficiency of the leachate collection system.

Regional precipitation and evaporation are two factors controlled by the geographical location of the facility. Variation of these parameters has a significant effect on leachate production rates as discussed below.

Soil parameters that influence cell design include required thickness and hydraulic conductivity. These parameters must be evaluated for soils used for cell capping, sand and gravels used in lateral drainage layers, soil barriers, and waste material.

Several models exist for the evaluation of climatological conditions and soil properties in the design of a land disposal facility. The latest and most sophisticated model available is the Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al., 1984), which was developed by the U.S. Army Engineer Waterways Experiment Station for the EPA.

The HELP model estimates leachate production rates by conducting a water balance for the land disposal system. Leachate production rates can be estimated for either a disposal facility in a filling mode or closure mode. Water balance data are summarized into tables of both monthly and yearly values. Percolation rates are calculated by subtracting surface water runoff, evapotranspiration, leachate removal from drainage layers, and the change in soil storage from the total precipitation. The HELP model will take into account FML drainage barriers. A leakage factor must be specified to reflect installation defects resulting in leaks.

For the purposes of this task, synthetic liners were not considered in evaluation of the cover and liner system performance using the HELP model, although they are an integral part of the leakage barrier system. This is part of a conservative approach to calculating the facility's protective life. Neglecting the FML's contribution to protection after an initial period of effectiveness reflects the fact that they have been manufactured for only a few years and their long-term performance has not been demonstrated, although there is no theoretical reason they should not last for hundreds of years. Since progressive deterioration of FML performance could be modeled only arbitrarily, it was decided to neglect the FML altogether after an initial leak-tight period.

The configuration of the cover and liner system was chosen by running a number of test cases for a closed landfill using the HELP model and comparing percolation rates from the base of the cover. Selection of the cover and liner system was divided into three steps: evaluation of soil layer thicknesses; evaluation of the number of lateral drainage layers; and layout of the leachate collection system. The best configuration from the first step will be further investigated in the second step and so on for the second and third steps.

Five cover systems were evaluated, as shown in Table 5-2, to determine the effect of the number of lateral drainage layers and thicknesses of soil layers. Cover No. 1 contains a 36 in soil cover layer underlain by two lateral drainage layers and two 24 in clay barriers. Cover No. 2 is similar to No. 1, except that it contains only one lateral drainage layer and one 36 in clay barrier. Cover Nos. 3, 4, and 5 are all variations of cover No. 2, with thicknesses of the cover layer and soil barrier varied.

A comparison of cover layouts 1 and 4 provides a basis to evaluate the benefit of two lateral drainage layers. A comparison of

TABLE 5-2

COVER SYSTEM

Layer	Cover No. 1	Cover No. 2	Cover No. 3	Cover No. 4	Cover No. 5
Topsoil (in)	36	36	24	36	36
Lateral drainage (in)	12	12	12	12	12
Soil barrier (in)	24	---	---	---	---
Lateral drainage (in)	12	---	---	---	---
Soil barrier (in)	24	36	36	24	48
Percolation from base of cover (in/yr)	0.5099	0.5232	0.5236	0.5252	0.5221

the average annual percolation rates shows less than a 3 percent increase in percolation rates when the second lateral drainage system was eliminated from design No. 4. Based on the small gain in efficiency, the added cost of an additional drainage layer was not deemed economically justified and hence was eliminated from further evaluation.

Covers 2 and 3 evaluate the thickness of the topsoil. Comparison of Nos. 2 and 3 shows there is negligible increase in percolation rates when the topsoil thickness is decreased from 3 to 2 feet. Based on modeling results, a 2 foot soil cover layer is adequate for design purposes but, as discussed at the end of this section, a 1 foot crushed rock barrier will be added to the cover layer to provide protection from burrowing animals, therefore, the 3 foot thickness will be used. Covers 2, 4, and 5 were used to evaluate the thickness of clay barriers. A comparison of Nos. 2 and 4 shows that decreasing the thickness of clay barriers from 3 to 2 feet increased percolation rates 0.002 in. per year. Likewise, increasing the thickness from 3 to 4 feet (Covers. 2 and 5) reduced percolation rates by 0.001 in per year. Commonly, clay barriers less than 3 feet thick are not used in hazardous waste facilities; therefore, a 3 foot barrier thickness is recommended. The EPA guidance documents also support the use of a minimum of 3 foot clay barriers (EPA, 1985c).

A summary of the results from the step one analyses recommends a cover system, one lateral drainage layer, a 36 in soil cover, and one 36 in clay barrier. These results correspond to the No. 2 cover system.

The effect of hydraulic conductivity on lateral drainage efficiency for the No. 2 cover system is evaluated in Table 5-3. Table 5-3 shows that percolation rates are greatly sensitive to changes in hydraulic conductivity of lateral drainage layer. The higher the hydraulic conductivity the more water the drainage layer will remove and hence

TABLE 5-3

EFFECT OF HYDRAULIC CONDUCTIVITY*
ON LATERAL DRAINAGE

Case Number	1	2	3	4
Hydraulic conductivity (in/hr)	14.7	150	1,500	9,999**
Percolation from base of cover	0.4911	0.2327	0.1327	0.0345

* Based on cover system No. 2 from Table 5-2.
** Maximum hydraulic conductivity accepted by model.

less percolation can occur. A hydraulic conductivity of 1,500 in/hr is recommended because it is the upper limit for a sand and gravel drainage layer (USBR 1977).

Details of the leachate collection system have a significant effect on percolation rates. Using the results from the steps 1 and 2 of the analysis, Table 5-4 provides a summary of the evaluation of the slope of the sawtooth collection system and spacing of lateral collection pipes. Covers 1 and 4 show that increasing the slope from 3 to 4 percent reduced percolation rates by 9 percent. As expected, percolation rates decrease as the sawtooth slopes increase. From a construction standpoint, the 3 percent slopes are recommended because they are easier to build and require less fill material.

Covers 1 and 3 show that decreasing the lateral spacing from 150 to 50 feet reduced percolation rates by 21 percent. A lateral spacing of 50 feet is considered to be a minimum because closer spacing would require cutting of FML sheets, which is undesirable because every added field seam is another potential leakage pathway as well as an additional expense.

A topic requiring further discussion is protection of the cover system from plant and animal intrusion. A study by Gano et al. (1982) states that an unknown animal burrowed into a radioactive waste disposal site and exposed radioactive waste. Gano further states that burrowing animals can move large amounts of soil and represent a serious threat to the integrity of an inground waste disposal site if it is left unrestricted.

Of prime concern among burrowing animals found at the RMA is the prairie dog, which is known to inhabit much of RMA. Gano reported that white- and black-tailed prairie dogs are known to burrow as deep as 6 and 14 feet, respectively.

Design of an effective barrier to animal intrusion is discussed in a study by Cline (1982). Cline found that prairie dogs could pierce a

TABLE 5-4

EVALUATION OF SLOPE AND LATERAL
SPACING OF LEACHATE COLLECTION SYSTEM

Case Number	1	2	3	4	5
Slope (percent)	3	3	3	4	4
Lateral spacing (center to center)	150	100	50	100	150
Percolation from base of cover (in/year)	0.52	0.465	0.369	0.421	0.474

* Based on Cover System No. 2.

6-inch layer of 1 to 1.5 inch crushed stone placed 18 inches below the soil surface. Since no information is available on larger stones, it is assumed that a 12 inch layer of crushed stone 3 to 6 inches in diameter will form an effective prairie dog barrier. This assumption is based on best engineering judgment and is subject to field verification.

As shown in Table 5-2, the thickness of the uppermost soil layer has little effect on percolation from the base of the cover. The depth of the evaporative zone was held constant in the study reported in Table 5-2. The depth was set at 8 inches in accordance with the recommendations of the HELP Model User's Guide. In later studies, it was found that the percolation rate is very sensitive to changes in the evaporative zone depth, and that the realistic value for that depth is much greater than 8 inches (see the discussion in Section 5.4.3). Therefore, the values shown are not used in the estimate of facility protective life. However, it is considered that the selection of layer thicknesses using a fixed depth of evaporative zone is valid.

Selection of the thickness is, therefore, controlled by the necessity to establish an effective barrier against burrowing animals and to provide sufficient topsoil and bedding material to establish a thick plant growth. Based on these considerations, a 3 foot cover layer is recommended. The lower 12 in of the cover layer will be crushed rock, 3 to 6 inches in diameter, overlain with 16 inches of random fill covered with 8 inches of topsoil.

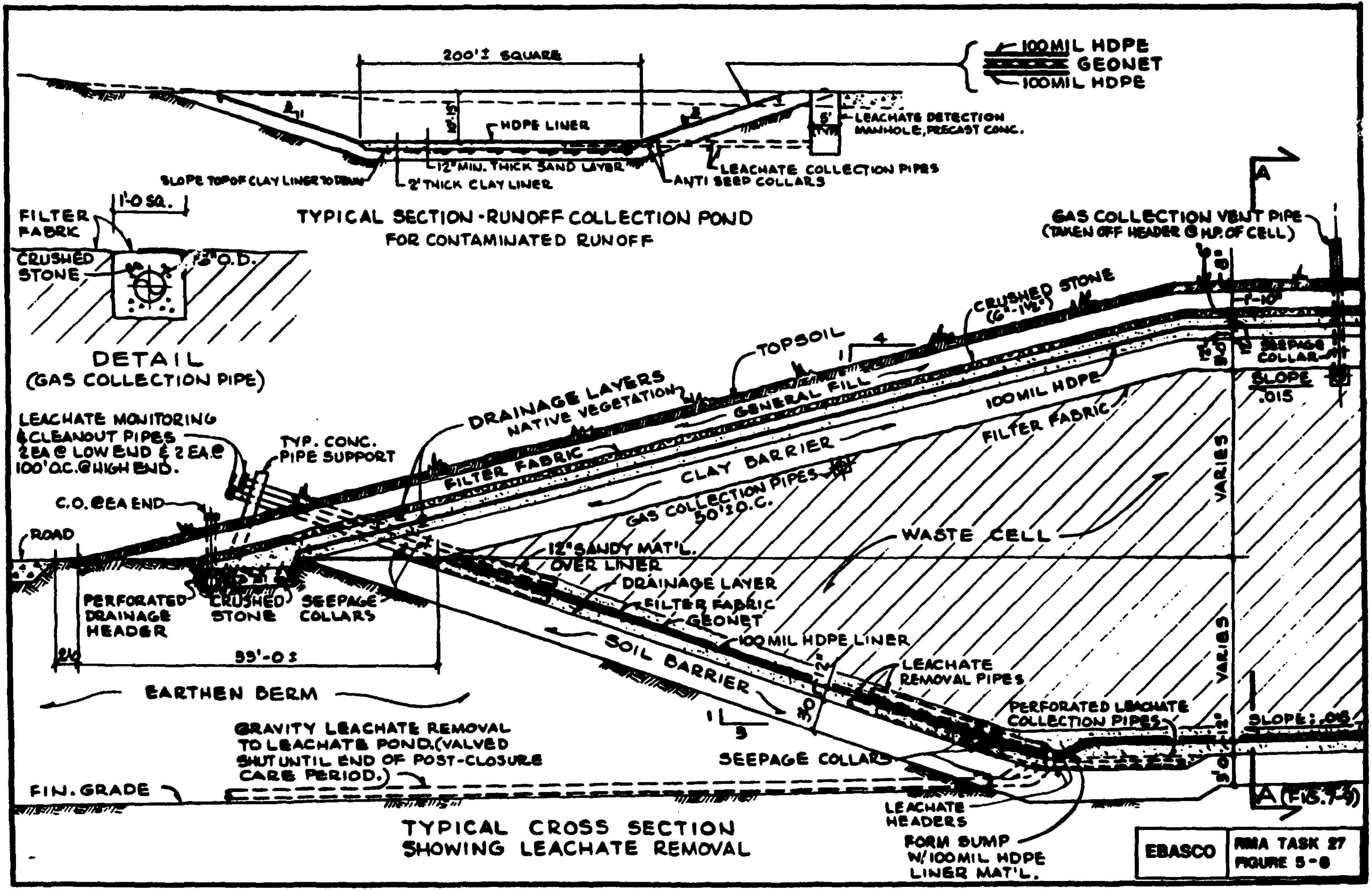
The topsoil will be revegetated with a native grass mixture consisting predominantly of western wheat grass. It is not envisioned that deep rooting plants will take hold on the cover because of the lack of soil moisture in the lower soil layers. The lateral drainage layer will effectively move excess moisture away from the cover and into the drainage sumps located along the cell periphery.

5.4.2 Selection of Liner System

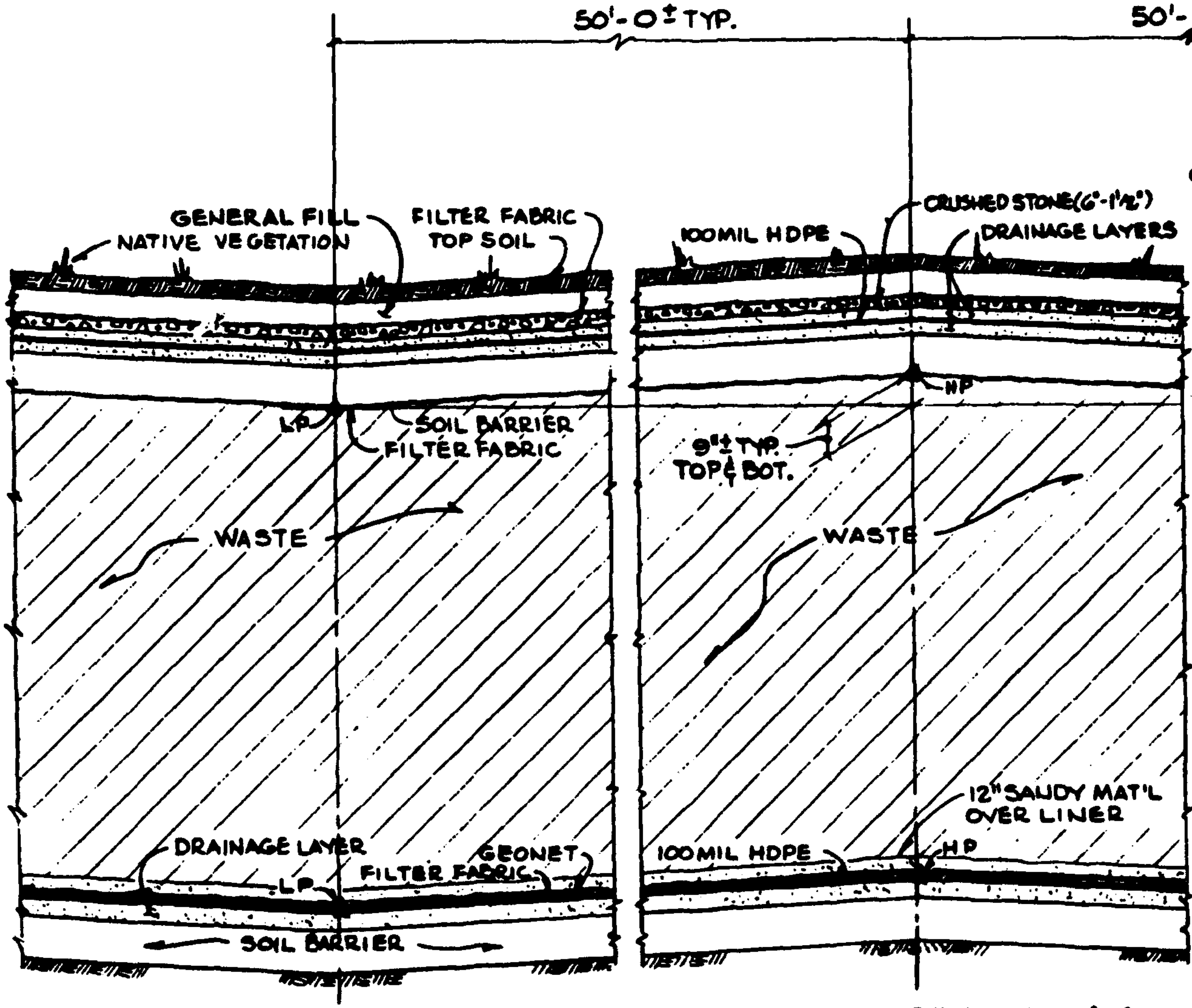
As discussed in the EPA draft Guidance Document on double liner systems, a liner system is required to have both leachate collection and detection layers (EPA, 1985c). The leachate collection system is assumed to be operated until leachate is no longer detected. The leachate detection layer is expected to function throughout the facility's protective life. The leachate collection layer is proposed to be constructed of a geonet underlain by a 100 mil FML. The leachate detection layer is proposed to be constructed of a sand drainage layer underlain by a soil barrier.

The HELP model treats the liner system and cover system identically; therefore, the design parameters from the cover system can be applied to the liner system. These design parameters are: a 3 percent slope on a sawtooth configuration, a 50 foot lateral spacing distance for leachate collection pipes, and a 3 foot thick soil barrier. Cross-sections of the liner system are shown in Figures 5-8 and 5-9.

Two estimates of percolation rates through the cover and liner system are presented in Table 5-5. Both of these estimates are based on an 8-inch evaporative zone depth and are not used in the estimate of facility protective life in Section 5.4.3; see the discussion of evaporative zone depth presented there. The first estimate is based on the default value for a surface runoff curve number used by the HELP model to calculate the amount of surface water runoff from the cap of the cover system. Default values are assigned by the HELP program if the user does not have site-specific values to substitute. Default values are based on regional information, in this case, the Denver region. The second estimate is based on a curve number calculated from available RMA soil data. The model shows that percolation rates are relatively insensitive to modest changes in the curve number.

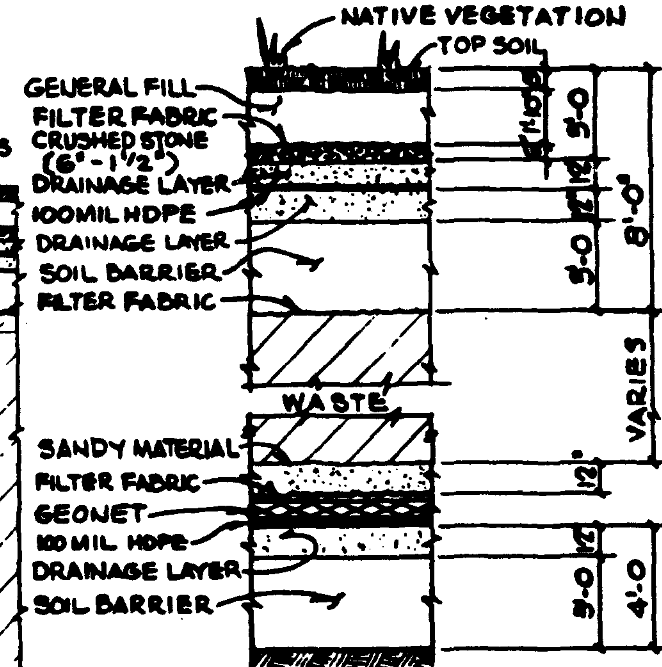


200'± SQUARE
100MIL HDPE
GEONET
100MIL HDPE
HDPE LINER
LEACHATE DETECTION MANHOLE, PRECAST CONC.
12" MIN. THICK SAND LAYER
2' THICK CLAY LINER
SLOPE TOP OF CLAY LINER TO DRAIN
ANTI SEEP COLLARS
LEACHATE COLLECTION PIPES
TYPICAL SECTION - RUNOFF COLLECTION POND
FOR CONTAMINATED RUNOFF
FILTER FABRIC
1'-0 SQ.
CRUSHED STONE
DETAIL
(GAS COLLECTION PIPE)
GAS COLLECTION VENT PIPE
(TAKEN OFF HEADER @ H.P. OF CELL)
CRUSHED STONE (6"-1½")
TOPSOIL
DRAINAGE LAYERS
NATIVE VEGETATION
GENERAL FILL
100 MIL HDPE
FILTER FABRIC
CLAY BARRIER
GAS COLLECTION PIPES 50'±O.C.
SEEPAGE COLLAR
SLOPE .015
VARIES
WASTE CELL
LEACHATE MONITORING & CLEANOUT PIPES 2 EA @ LOW END & 2 EA @ 100' O.C. @ HIGH END.
TYP. CONC. PIPE SUPPORT
C.O. @ EA END
ROAD
12" SANDY MAT'L. OVER LINER
DRAINAGE LAYER
FILTER FABRIC
GEONET
100 MIL HDPE LINER
PERFORATED DRAINAGE HEADER
CRUSHED STONE
SEEPAGE COLLARS
33'-0±
SOIL BARRIER
LEACHATE REMOVAL PIPES
PERFORATED LEACHATE COLLECTION PIPES
SLOPE: .015
EARTHEN BERM
GRAVITY LEACHATE REMOVAL TO LEACHATE POND. (VALVED SHUT UNTIL END OF POST-CLOSURE CARE PERIOD.)
SEEPAGE COLLAR
FIN. GRADE
LEACHATE HEADERS
FORM SUMP W/100 MIL HDPE LINER MAT'L.
A (FIG. 7-9)
TYPICAL CROSS SECTION
SHOWING LEACHATE REMOVAL
EBASCO
RMA TASK 27
FIGURE 5-8



NOTE:
TOP & BOTTOM SAWTOOTH SECTIONS ARE NOT NECESSARILY IN LINE AS SHOWN.

TYPICAL SECTION A (FIG. 7-8)
SHOWING SAWTOOTH TOP & BOTTOM



RECOMMENDED LINER & COVER SYSTEM
BASED ON RESULTS FROM THE HELP MODEL

EBASCO
RMA TASK 27
FIGURE 5-9

TABLE 5-5

ESTIMATE OF COVER AND LINER SYSTEM PERFORMANCE

	Case No. 1	Case No. 2
Percolation from base of cover (in/yr)	0.1022	0.1024
Percolation from base of landfill (in/yr)	0.0698	0.0701
Drainage from base of cover (in/yr)	1.995	2.007
Drainage from base of landfill (in/yr)	0.032	0.032
Hydraulic conductivity of soil (in/yr)	0.63	0.63
Surface runoff curve number	84.4	71

The studies described above were performed using the default precipitation data contained in the HELP Model, which provided an annual average rainfall of 13 inches. An analysis of the rate of percolation through the cover and liner system was also performed using 20 years of daily precipitation data from 1963 to 1982, for which period average annual rainfall was more than 15 inches compared to the 13 inches in the HELP model. The 16-1/2 percent increase in rainfall increased percolation through the cover system by only 4 percent, which shows that percolation rates are relatively insensitive to minor changes in annual precipitation.

5.4.3 Environmental and Public Health Implications

As discussed in Chapter 6, waste containment is a primary design objective to ensure protection of the public health and environment. In this context, containment means isolation of the waste from contaminating the underlying aquifer. Containment of waste is readily assured while the FMLs are still intact. At some point in time the performance of the FMLs will degrade (i.e., leakage occurs). In the conservative approach used here, it is assumed that no maintenance will take place. Therefore, the containment life of a cell is considered to be the leak-tight life of the liner plus the time required for leachate to travel through the cell and reach the groundwater.

Estimating the design life of FMLs is subjective. Manufacturers typically guarantee liners to be free of defects for 20 years. In the protected environment offered by a thick soil cover, an inert liner material such as HDPE should last indefinitely. For calculation purposes, the leak-tight life was assumed to be the post-closure monitoring period, following which the FML was assumed to be completely ineffective. This is believed to be a very conservative assumption, since, in reality, even a deteriorated FML barrier would offer some flow resistance.

Estimating the travel time of water through the waste cell is based on the percolation rates estimated with the HELP Model (Table 5-6) and the cell cross-section shown in Figure 5-9.

In the first method (Column 7), each soil layer below the uppermost FML absorbs a quantity of water before it begins to transmit water. The containment calculations are based on the quantity of water these layers absorb. Figure 5-10 diagrammatically illustrates the downward percolation of water through the cell's cover and liner system.

Field capacity values were taken from default values found in the HELP model documentation, which were found to be the same as those in the Adams County Soils Report. The in situ soil saturation values were calculated from soil data (unit weight, moisture content, and porosity) obtained from soil investigation reports originally prepared by various parties for foundation design in the South Plants area, and for other purposes, and presently available in the Shell database for RMA (Shell, undated). Fifty-six moisture content and dry density determinations were retrieved from eight reports in the database, mostly for silts and sands, lying above the water table at a mean depth of 10.6 feet. Values of field capacity and hydraulic conductivity were chosen from the default soil characteristics provided in the HELP Model User's Guide (Table 2, Soil 8, silty soil with Unified Soil Classification SM). The porosity was calculated from the database soils reports using an assumed mineral specific gravity of 2.7, the lowest value for which the measured water content did not significantly exceed the calculated saturation water content in any sample, and a very typical value for a wide range of soils.

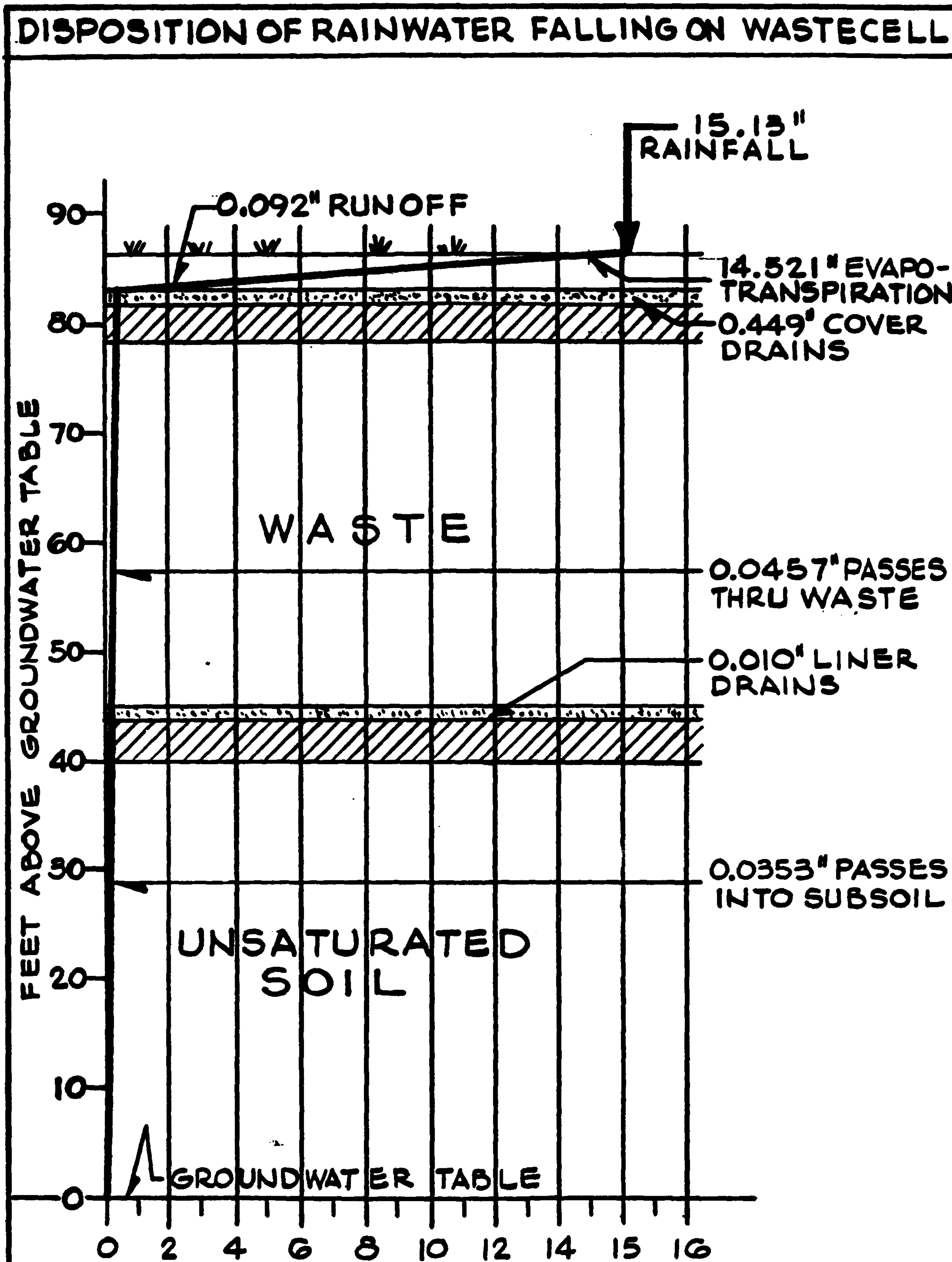
The models used in selection of the waste cell cover and liner components were based on an evaporative zone depth of 8 inches, which was obtained from the HELP Model User's Guide. The Guide suggests that conservative values of evaporative depth range from 4 inches for bare ground to 10 inches for a fair stand of grass. It was judged that a poor stand of grass would fall between these values; hence, 8 inches was selected for this part of the work.

TABLE 5-6

TRAVEL TIME THROUGH ELEMENT

	(1) Layer Thickness In	(2) Field Capacity Vol/Vol	(3) In Situ Moisture Vol/Vol	(4) Storage Capacity (2)-(3)	(5) Soil Storage (1)*(4)	(6) Percolation Rate (in/yr)	(7) Time Yrs (5)/(6)	(8) Time Yrs EPA method
Realistic Model - Intermittent Percolation								
Clay barrier (cover)	36	0.450	0.400	0.050	1.80	0.0004	4500	34510
Waste layer	420	0.256	0.230	0.026	10.92	0.0004	27300	114335
Clay barrier (liner)	36	0.450	0.400	0.050	1.80	0.0004	4500	34510
Unsaturated Soil*	450.8	0.256	0.144	0.112	50.37	0.0004	125931	122719
					Total		162231	306074
Conservative Model - Continuous Percolation								
Clay barrier (cover)	36	0.450	0.400	0.050	1.80	0.0457	39	361
Waste layer	420	0.256	0.230	0.026	10.92	0.0457	239	1411
Clay barrier (liner)	36	0.450	0.400	0.050	1.80	0.0457	39	361
Unsaturated Soil*	450.8	0.256	0.182	0.074	33.17	0.0457	726	1514
					Total		1044	3648

* Based on a 40-ft depth to groundwater minus 29.2 inches of capillary rise.



EBASCO

RMA TASK 27
FIGURE 5-10

In April 1988, the principal author of the HELP Model published a paper (Peyton & Schroeder, 1988) in which he reassessed the recommended value of evaporative depth. Acknowledging that small changes in evapotranspiration can have major impacts in volumes of lateral drainage and barrier soil percolation, and analyzing field data from six landfill sites across the United States, he concluded that, "better results, though less conservative, would be expected by using evaporative depths that are 50 to 100 percent larger than suggested by the User's Guide for the model. Even larger depths should be used for landfills in arid and semiarid climates."

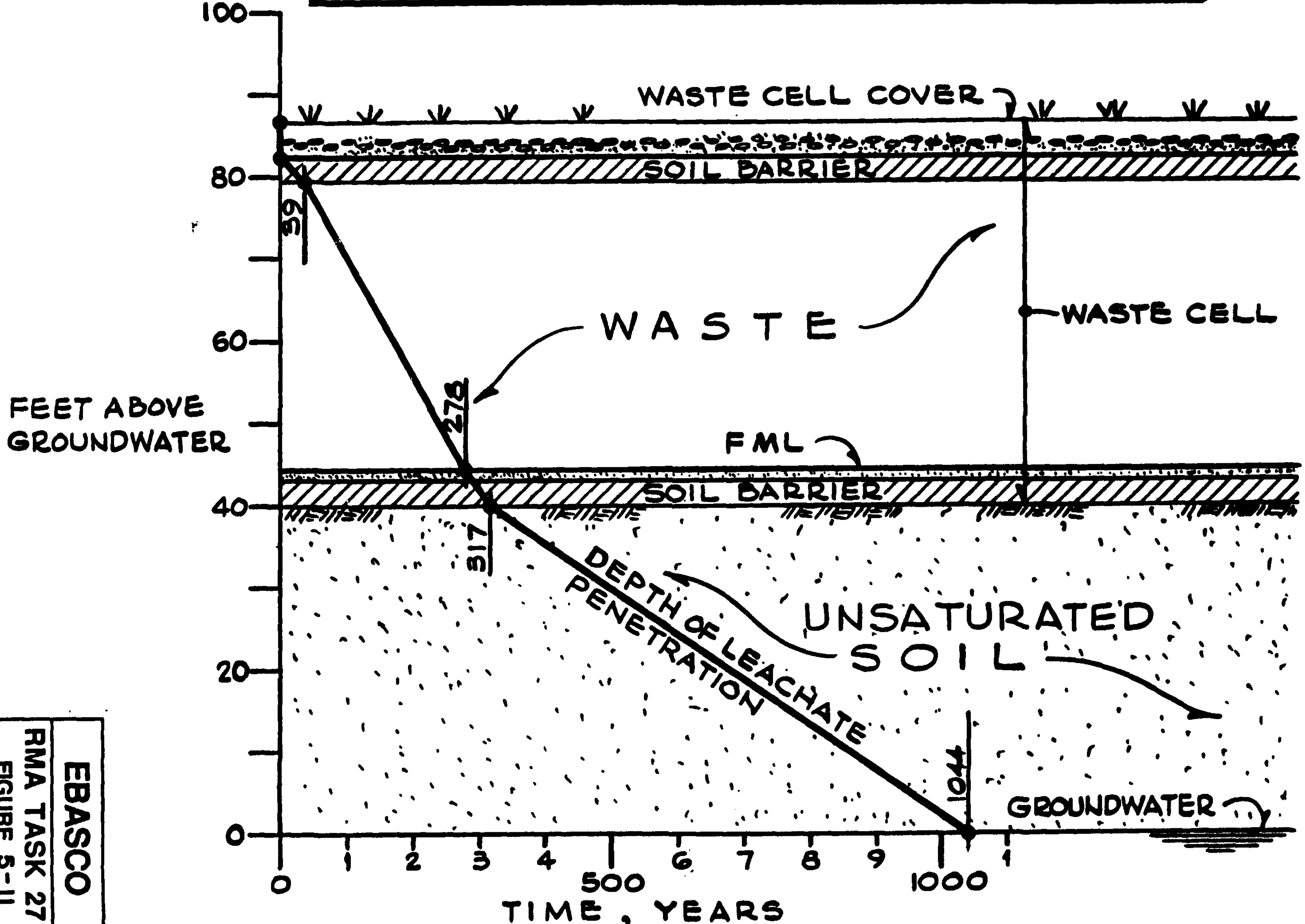
On the basis of this reassessment, the evaporative zone depth used for estimating the protective life of the facility has been set at 24 inches. This value is within the typical effective root zone depths of the wild prairie grasses, primarily blue grama and western wheatgrass, which are expected to establish themselves on the cover as the dominant form of vegetation over the long term (Sampson & Baber, 1974).

The total number of years of waste containment is the sum of the successive layer travel times from the top of the clay barrier in the cover to the groundwater table. Figure 5-11 illustrates the travel time of water through the cell's cover and liner systems calculated by this method.

In the second method (Column 8), which is based on EPA time-of-travel methodology (EPA, 1986a), the hydraulic resistance of the soil is considered as well as the state of saturation. This method was applied to the same database soil properties and percolation rate, with the results in Column 8 seen to be longer for most layers than those obtained using the first method. The overall prediction of protective life is two to three times longer.

Table 5-6 also illustrates the effect of changing the way in which the HELP Model models percolation.

PROTECTIVE LIFE OF DISPOSAL FACILITY



EBASCO

RMA TASK 27
FIGURE 5-11

In the upper part of the table a time-of-travel calculation is displayed based on a percolation rate (Column 6), which is obtained using the assumption that there is little capillary suction to draw water into the lower layers and that percolation does not occur until the soil moisture in the evaporative zone exceeds the field capacity. This is considered realistic for the waste cell cover design here, and so the calculation is labeled "REALISTIC MODEL-INTERMITTENT PERCOLATION."

In the lower part of the table, a calculation is presented based on a percolation rate obtained using the opposite assumption, that is, that water is drawn into the lower layers by capillary suction when infiltration occurs. This assumption is applicable for typical landfill designs where the top layer is a vegetated topsoil with a shallow water table. The water table at the recommended primary site on RMA lies at a depth of 40 feet below the bottom of the waste cell, and 80 feet below the cover of the waste cell configuration recommended here; the action of capillary suction is limited to a zone of a few feet above the water table. In addition, the cover includes a drainage layer that would break any action of capillary suction across it. For these reasons, this calculation is labeled "CONSERVATIVE MODEL - CONTINUOUS PERCOLATION." This calculation yields the shortest estimate of protective life, 1,044 years.

In summary, the 1,044 years of waste containment is a conservative lower-bound estimate for the following reasons:

1. The HELP model underestimates surface water runoff rates, which leads to overestimated percolation rates. For example, the Resource Consultants, Inc. (1982) study of surface water hydrology at RMA gives calculated average runoff from the First Creek Basin as 0.5 inch per year after impermeable areas are subtracted, whereas the HELP model gives only 0.1 inches, or about a fifth as much.

2. The FML was assumed to fail instantaneously at the end of the monitoring period, although in actuality its performance will degrade slowly.

3. A time of travel three times as long was calculated using unsaturated flow equations per the July 1986 EPA guidance manual on the determination of time of travel and "vulnerable hydrogeology."

4. The use of the continuous percolation model for the RMA climate and this waste cell design is extremely conservative. Continuous percolation assumes the action of capillary suction to draw groundwater downward through the soil when the soil moisture is below field capacity. This is only possible near (within a few feet of) the water table. Not only is the waste cell far from the water table, but any possible capillary suction is broken by the porous drainage layers. The intermittent percolation model is much more realistic for this situation.

These four reasons show the conservatism of the calculation of protective life, and are further evidence that a satisfactory demonstration of adequate protective life for a disposal facility can be achieved in any further development of this technology.

5.5 CELL CONSTRUCTION

A cross-section of the cell is shown in Figure 5-8. A collection sump located along the perimeter of the cell collects water that infiltrates the cover system. Water that collects in the sump is dissipated into the surrounding soil.

A gas collection system of perforated HDPE pipe is provided in the cover system to relieve any buildup of pressure. The pipe is bedded in a sand and gravel layer surrounded by a filter fabric blanket as

shown on Figure 5-9. Gas collection pipes run the length of the cell and are connected to a header pipe located on the high end of the cell. The header pipe is vented to the atmosphere after passing through an activated carbon filter to remove volatile organic vapors.

If the cover system breaches, water will percolate downward through the waste until it reaches the leachate collection layer. The leachate collection system will then drain by gravity to a leachate collection sump located at the low end of the cell. The leachate collection sump slopes to one side of the cell where a leachate clean-out and monitoring riser are located and where leachate, if generated, can be pumped and trucked to a regulated surface impoundment.

If a breach occurs in the leak detection layer, leachate will flow similarly to a collection sump located at the low end of the cell. During the post-closure care period, the leak detection layer will be monitored at a riser located next to the collection riser. After the post-closure care period, the leachate detection header pipe will be connected to a gravity drain pipe. The drain pipe will flow to the modified leachate pond (see Site Closure and Post-closure Care Plan, Appendix III). After connection of the drainage line, no further monitoring will be required of the cell. The cell will operate indefinitely in this mode if left undisturbed.

6.0 FACILITY CONFIGURATION

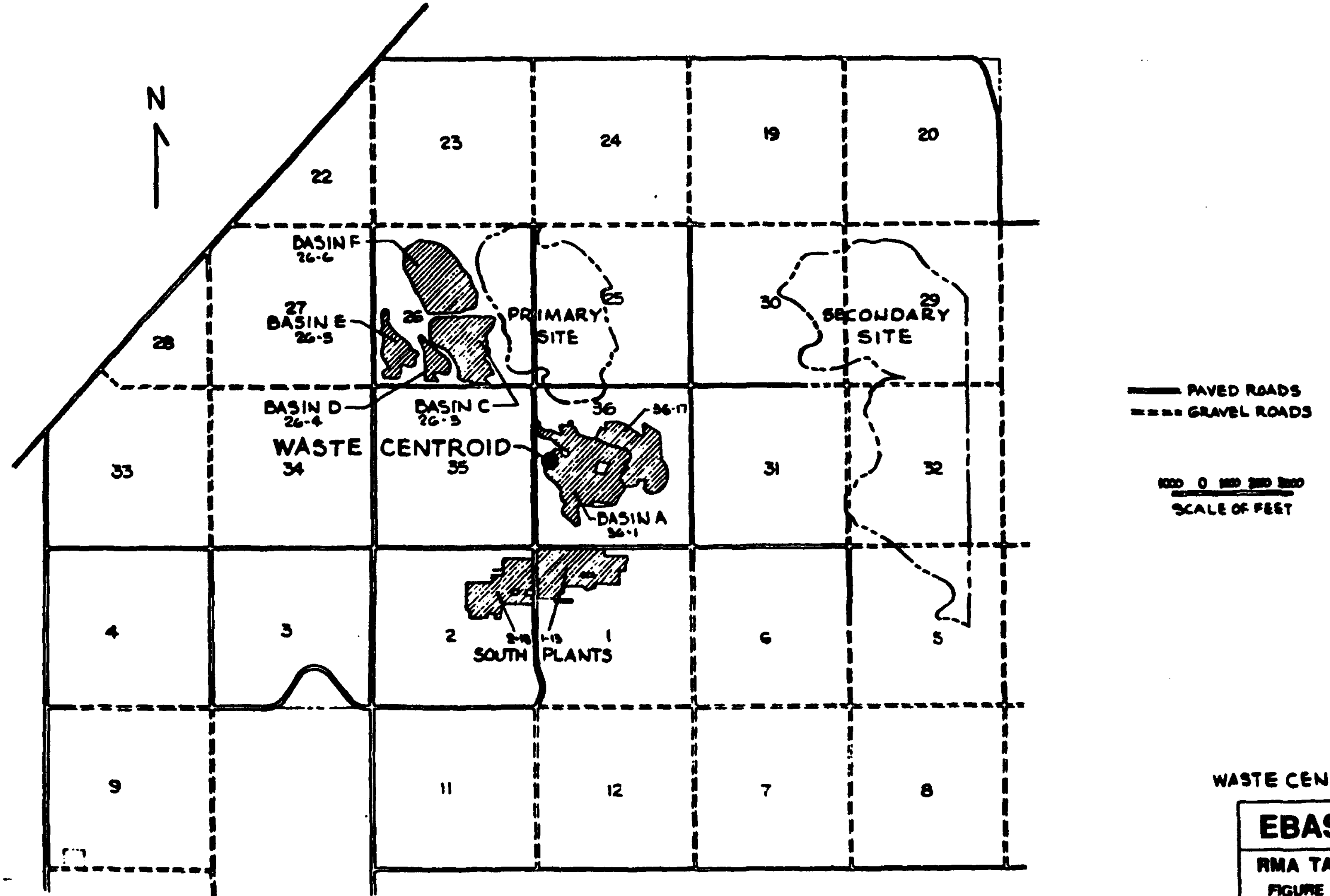
This chapter describes the requirements for preparing the site(s) for construction of a waste disposal facility and the development of alternate site layouts using the three waste cell sizes identified in Chapter 5 and the two recommended sites identified in Chapter 3. It is shown that a facility capable of disposing of 16 million cy can be located at either site. Supporting facilities such as haul roads and buildings were also considered.

The site selection process discussed in Chapter 3 recommended primary and secondary sites for construction of the land disposal facility. The primary and secondary sites are 400 and 1,050 acres in size, respectively. Figure 6-1 shows the general locations of the two sites.

6.1 SITE PREPARATION

Site preparation includes the installation of all facilities required to support construction of waste disposal cells. This includes clearing, grading, fences, haul and access roads, surface water control system, support buildings, and decontamination zones. Clearing and grading operations are dependent on the buildout period and may occur in phases.

Earthwork calculations were made for alternate facilities consisting of four different sizes of cells: 250,000; 1,000,000; 1,500,000; and 3,000,000 cy. The calculations were based on using the primary site and are summarized for each cell size in the cost estimates included in Chapter 7. A requirement for a source of fill material exists for all four cell sizes, ranging from 9.8 million cy for the 250,000 cy cells to 493,000 cy for the 3,000,000 cy cell. The larger quantity for the smaller cell is partly the result of the larger quantity of material needed for berm construction for the larger number of cells required to provide total facility capacity, and partly the result of additional site grading requirements.



WASTE CENTROID

EBASCO

RMA TASK 27

FIGURE 6-1

Following clearing and grading operations, the disposal site would be fenced to prevent the inadvertent or unauthorized entrance by livestock, wildlife, or humans.

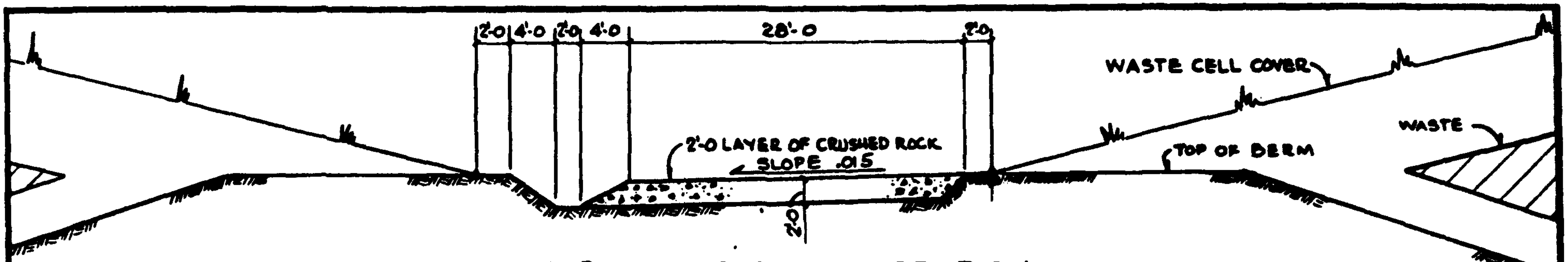
Haul roads are laid out to follow the existing section roads to the disposal site. Once at the disposal site, roads are laid out in a grid pattern. The grid pattern of cells is based on north-south and east-west access roads.

Haul roads would be covered with an asphalt surface to facilitate cleanup operations of spilled material. Access roads would be finished with a crushed rock layer. Typical sections of access and haul roads are shown on Figure 6-2.

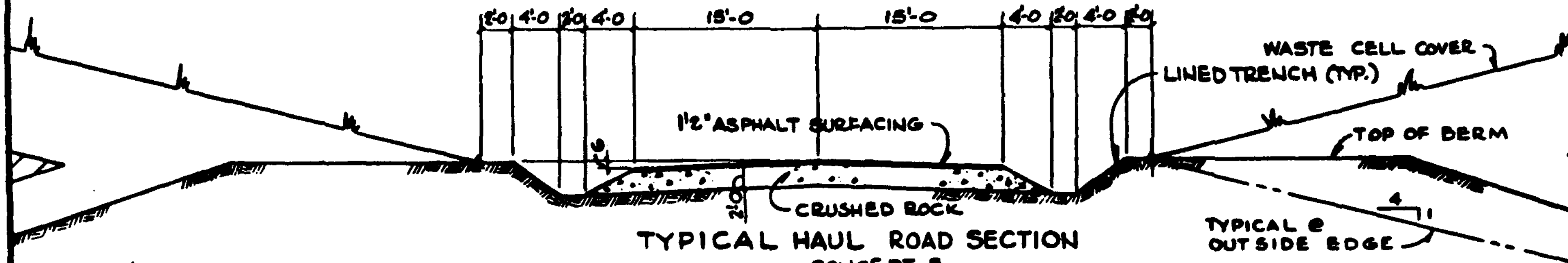
The surface water control system is designed to handle contaminated and uncontaminated runoff separately. Precipitation falling on an open cell or active haul road would be diverted or pumped to a lined evaporation pond. Uncontaminated surface water would be diverted to a detention basin and discharged into an ephemeral drainage. Diversion ditches along haul roads would be lined to minimize infiltration of potentially contaminated surface water.

Support buildings at the facility would consist of a maintenance garage, administration buildings, an analytical laboratory, and decontamination trailers. The maintenance garage, administration buildings, and laboratory would be constructed of prefabricated metal and located near the main entrance to the site. The analytical laboratory would be equipped to provide water quality, soil, and air analysis. The decontamination trailers would be transportable and moved in phases with construction. Three trailers would be used: one located at the waste excavation site, one at the disposal site, and the third at a standby trailer located near the administrative building.

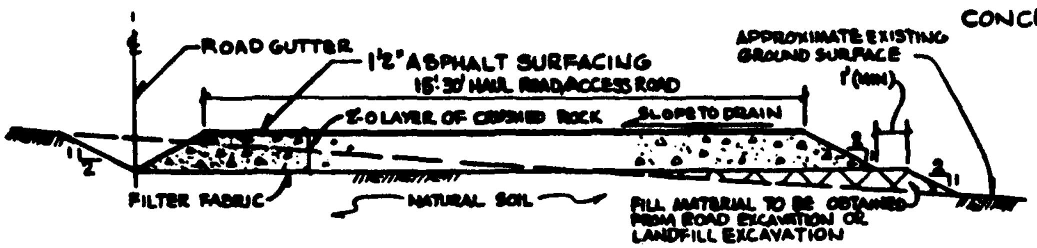
Before waste placement operations begin, decontamination facilities would be constructed at the waste removal site and the disposal facility. The decontamination facilities include a truck washing pad



TYPICAL ACCESS ROAD SECTION
CONCEPT B



TYPICAL HAUL ROAD SECTION
CONCEPT B



TYPICAL HAUL ROAD SECTION OUTSIDE OF FACILITIES AREA

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FIGURE 6-2

and pressure washer to remove contaminated soil from equipment prior to movement on haul roads. Rinse water from the truck washing operations would be pumped to a storage tank which would be periodically emptied into the evaporation pond or used for dust control in the active fill.

6.2 FACILITY LAYOUT

As discussed in Section 5.2, the waste cell dimensions were based on a waste depth of 35 feet, which was considered to be a minimum economic height. In order to evaluate the overall economic benefit of increasing the waste height, the intermediate cell size was also evaluated at a 60 foot waste height. Increasing the height of the intermediate cell to 60 feet increased the 1,000,000 cy cell volume by approximately 50 percent to 1.5 million cy. The economic analysis in Chapter 7, therefore, evaluates four cell sizes given that the intermediate size waste cell is evaluated at two waste heights.

Three facility layouts were prepared for both the primary and secondary sites, for a total of six layouts. These layouts show facility designs using small, intermediate, and large waste disposal cells, which correspond to 250,000; 1,000,000/1,500,000; and 3,000,000 cy cells. The small and large cells were chosen to bound the extremes of reasonable cell sizes, considering the rapid increase in cost for cells smaller than 250,000 cy and the apparent lack of precedent for extremely large cells.

The location of the primary site with respect to the location of waste at RMA is shown on Figure 6-3. The facility layouts for the small, intermediate, and large cells are shown in Figures 6-4, 6-5, and 6-6, respectively.

The primary site is graded to drain to the north on a 1.5 percent slope, with the exception of the 250,000 cy cell layout, which has a small area that drains to the south. This was done to reduce the quantity of

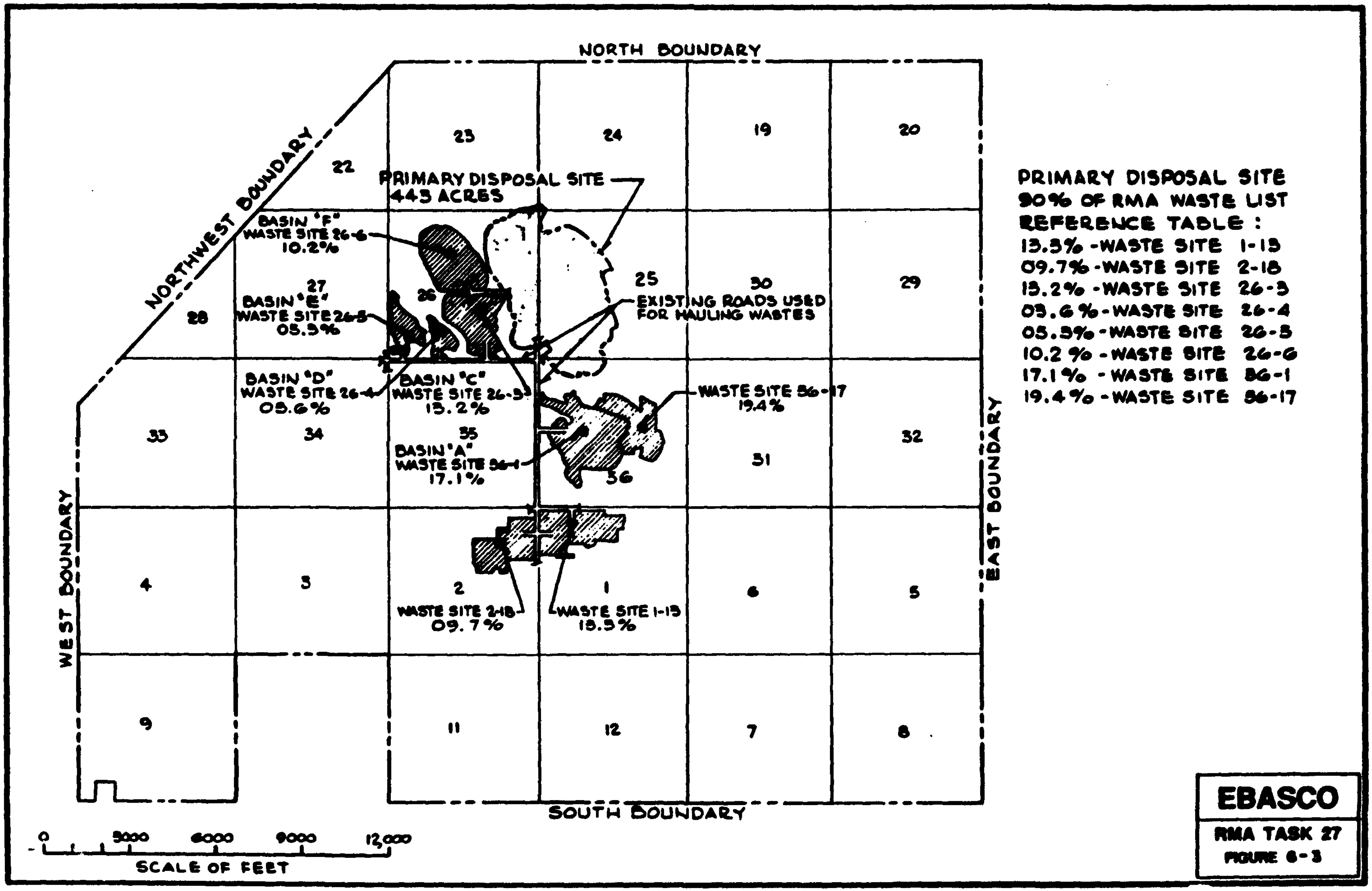
NORTH BOUNDARY
SOUTH BOUNDARY
EAST BOUNDARY
WEST BOUNDARY
NORTHWEST BOUNDARY
23
24
19
20
22
27
28
26
25
30
29
33
34
35
36
31
32
4
3
2
1
6
5
9
11
12
7
8
PRIMARY DISPOSAL SITE
443 ACRES
BASIN "F"
WASTE SITE 26-6
10.2%
BASIN "E"
WASTE SITE 26-5
05.5%
BASIN "D"
WASTE SITE 26-4
05.6%
BASIN "C"
WASTE SITE 26-3
13.2%
BASIN "A"
WASTE SITE 36-1
17.1%
EXISTING ROADS USED
FOR HAULING WASTES
WASTE SITE 36-17
19.4%
WASTE SITE 2-18
09.7%
WASTE SITE 1-15
13.5%
PRIMARY DISPOSAL SITE
90% OF RMA WASTE LIST
REFERENCE TABLE :
13.5% -WASTE SITE 1-15
09.7% -WASTE SITE 2-18
13.2% -WASTE SITE 26-3
05.6% -WASTE SITE 26-4
05.5% -WASTE SITE 26-5
10.2% -WASTE SITE 26-6
17.1% -WASTE SITE 36-1
19.4% -WASTE SITE 36-17
0
3000
6000
9000
12,000
SCALE OF FEET
EBASCO
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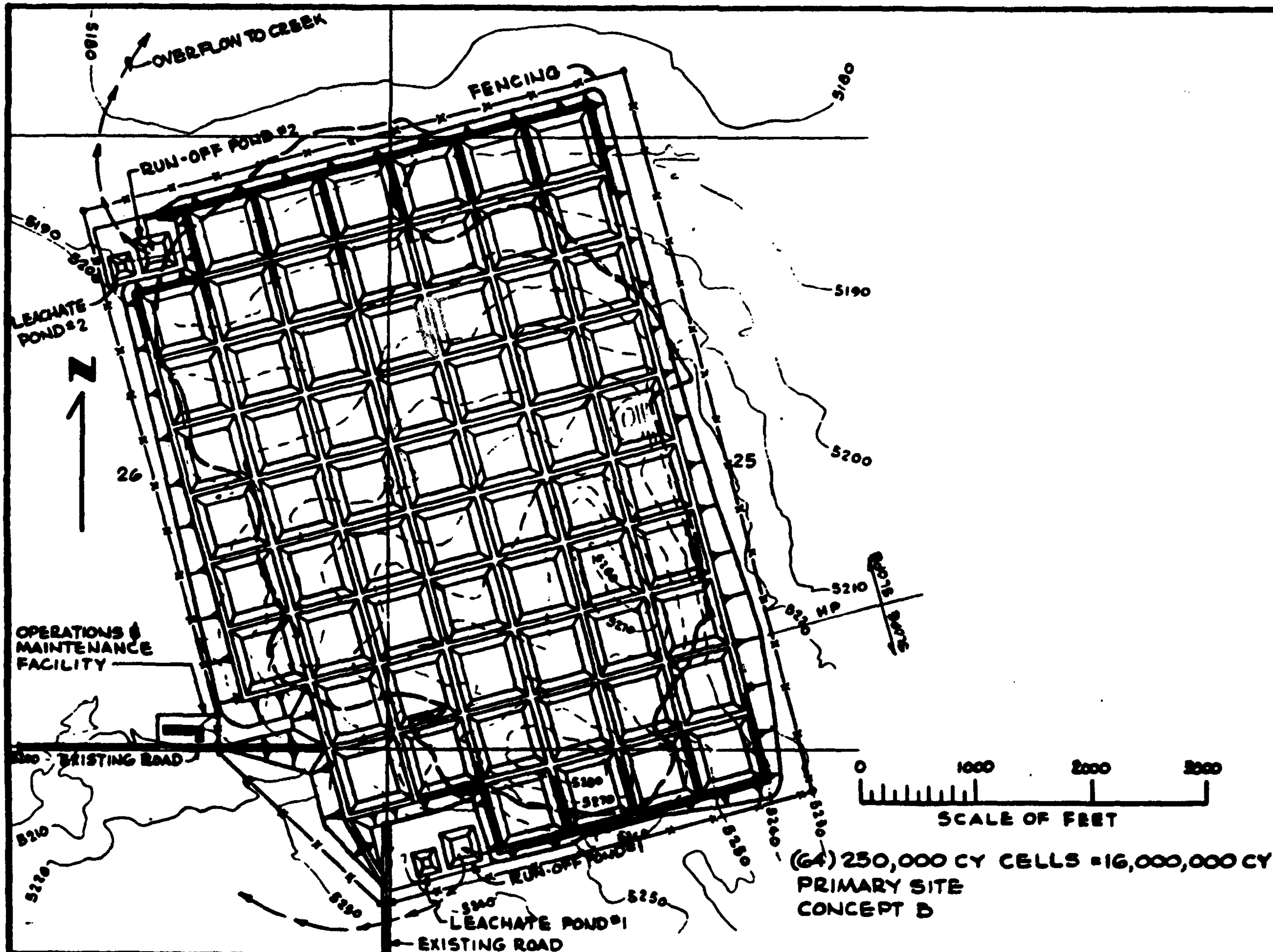
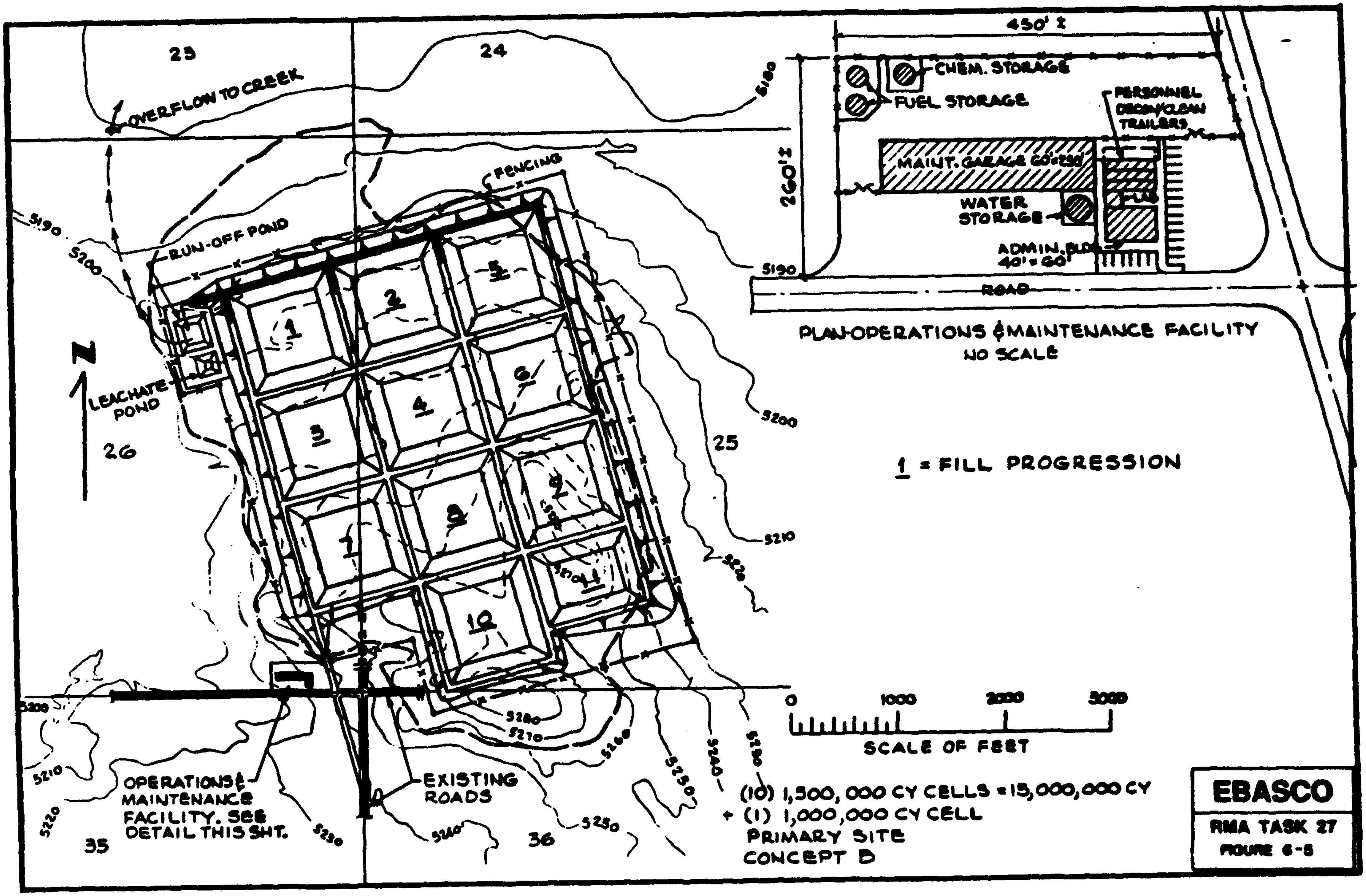
FIGURE 6-3

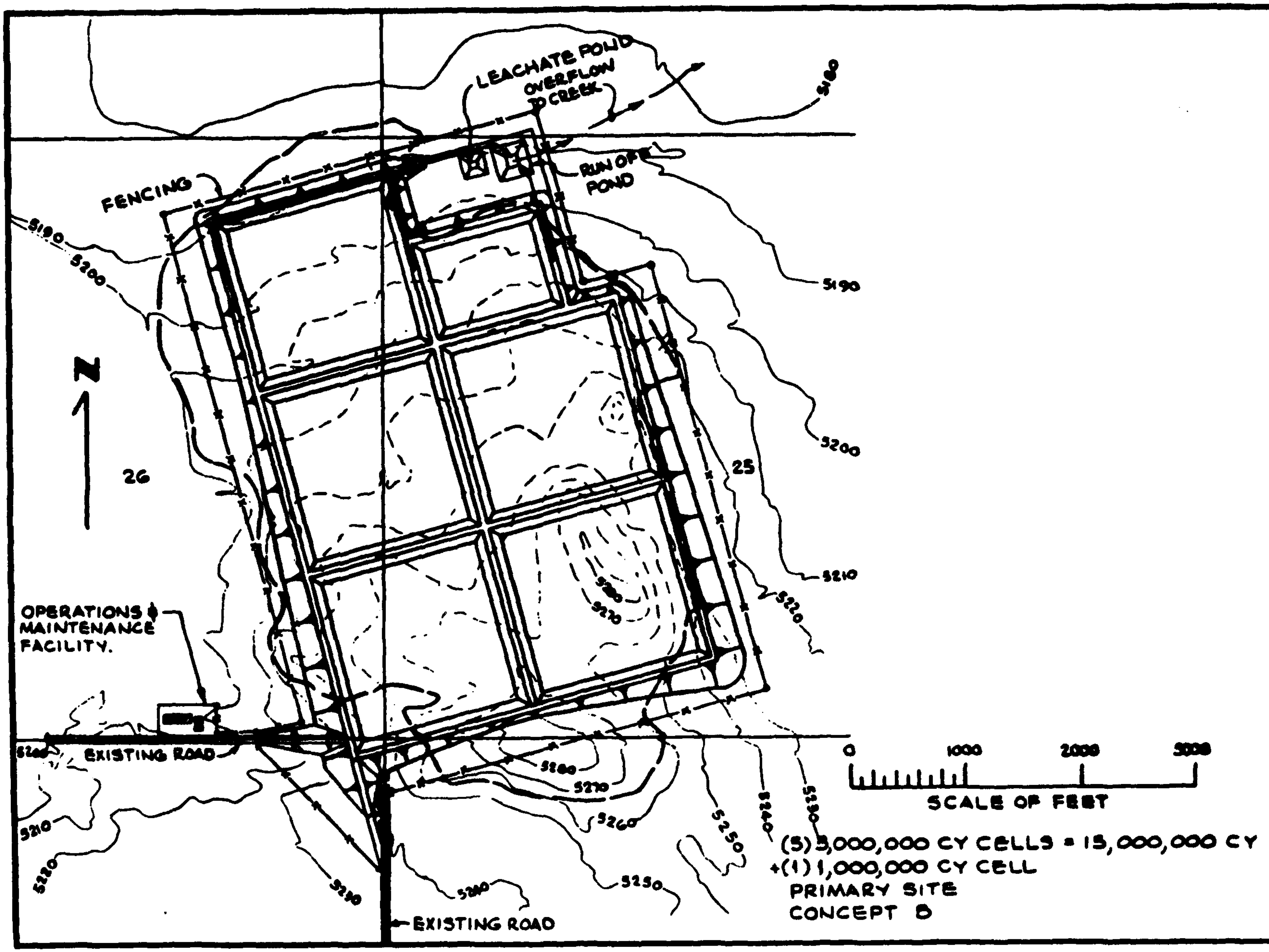


(64) 250,000 CY CELLS =16,000,000 CY
PRIMARY SITE
CONCEPT B

EBASCO
RMA TASK 27
FIGURE 6-4



23
24
25
26
35
36
OVERFLOW TO CREEK
RUN-OFF POND
LEACHATE POND
FENCING
N
1
2
3
4
5
6
7
8
9
10
11
5190
5200
5210
5220
5230
5240
5250
5260
5270
5280
OPERATIONS & MAINTENANCE FACILITY. SEE DETAIL THIS SHT.
EXISTING ROADS
450' ±
260' ±
CHEM. STORAGE
FUEL STORAGE
PERSONNEL DECON/CLEAN TRAILERS
MAINT. GARAGE 60'×230'
WATER STORAGE
LAB
ADMIN. BLDG. 40'×60'
ROAD
PLAN-OPERATIONS & MAINTENANCE FACILITY
NO SCALE
1 = FILL PROGRESSION
0
1000
2000
3000
SCALE OF FEET
(10) 1,500,000 CY CELLS = 15,000,000 CY
+ (1) 1,000,000 CY CELL
PRIMARY SITE
CONCEPT D
EBASCO
RMA TASK 27
FIGURE 6-5



(5) 3,000,000 CY CELLS = 15,000,000 CY
+(1) 1,000,000 CY CELL
PRIMARY SITE
CONCEPT B

EBASCO
RMA TASK 27
FIGURE 6-6

required fill material. As a result, the 250,000 cy cell layout requires surface water control facilities on both its north and south ends.

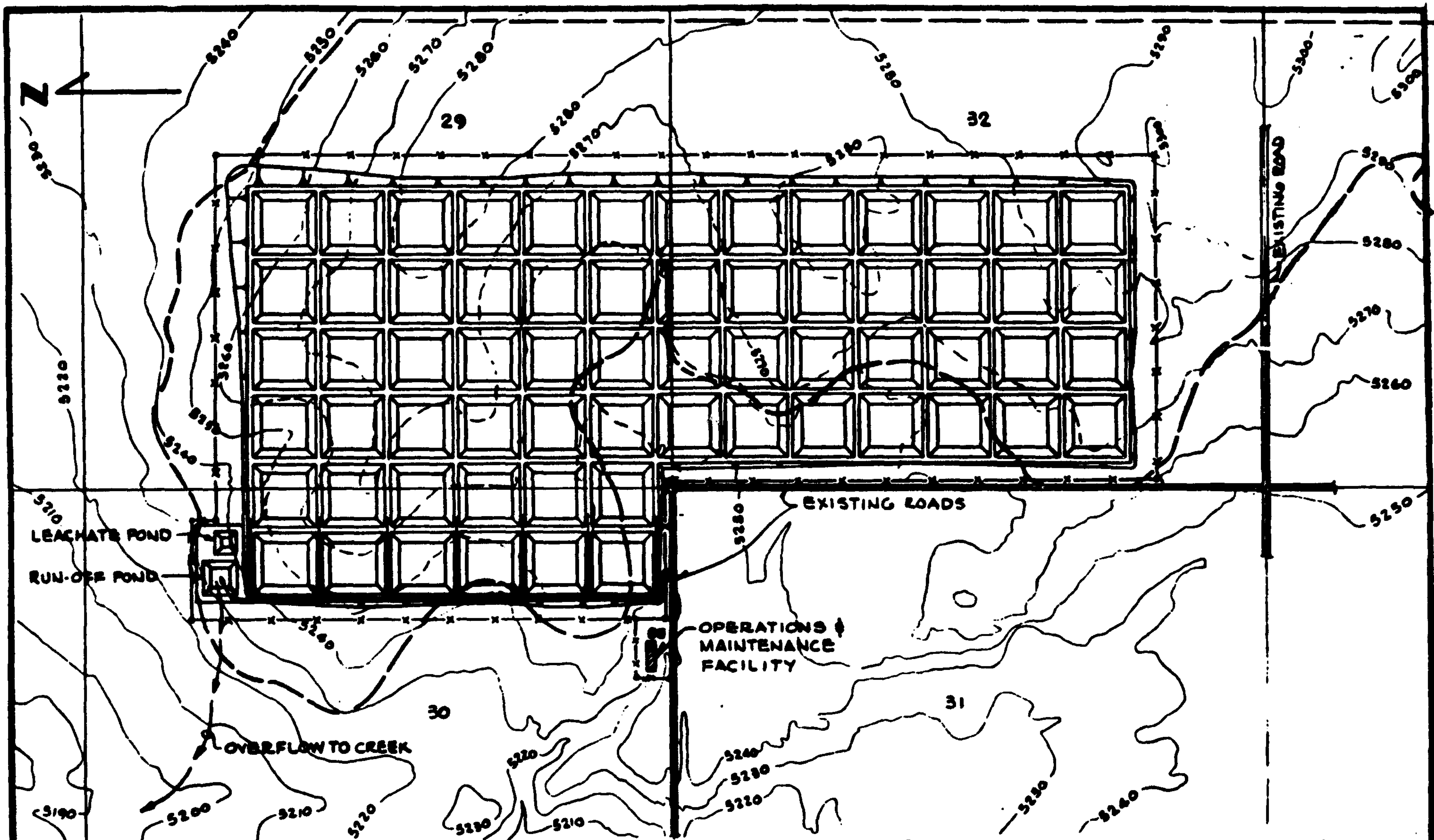
The location of the secondary site with respect to the waste material at RMA is shown in Figure 6-7. Layouts for the small, intermediate and large cells are shown in Figures 6-8, 6-9, and 6-10. The site is graded to drain to the west on a 1.5 percent grade.

It can be seen from the facility plans for both sites that the use of larger cells requires less site area for the facility. This results in an economic benefit because the amount of area to be prepared is reduced and the facility perimeter is shortened. This benefit reinforces the previously observed economy of construction of larger cells.

The facility boundaries shown exceed the disposal site boundaries in places. This is acceptable because the site boundaries are generally defined from the depth to groundwater calculations. The consequences of exceeding the site boundary are negligible unless the bottom of a waste cell projects outside the boundary. In that case, fill under the cell is required to reestablish the minimum depth to groundwater.

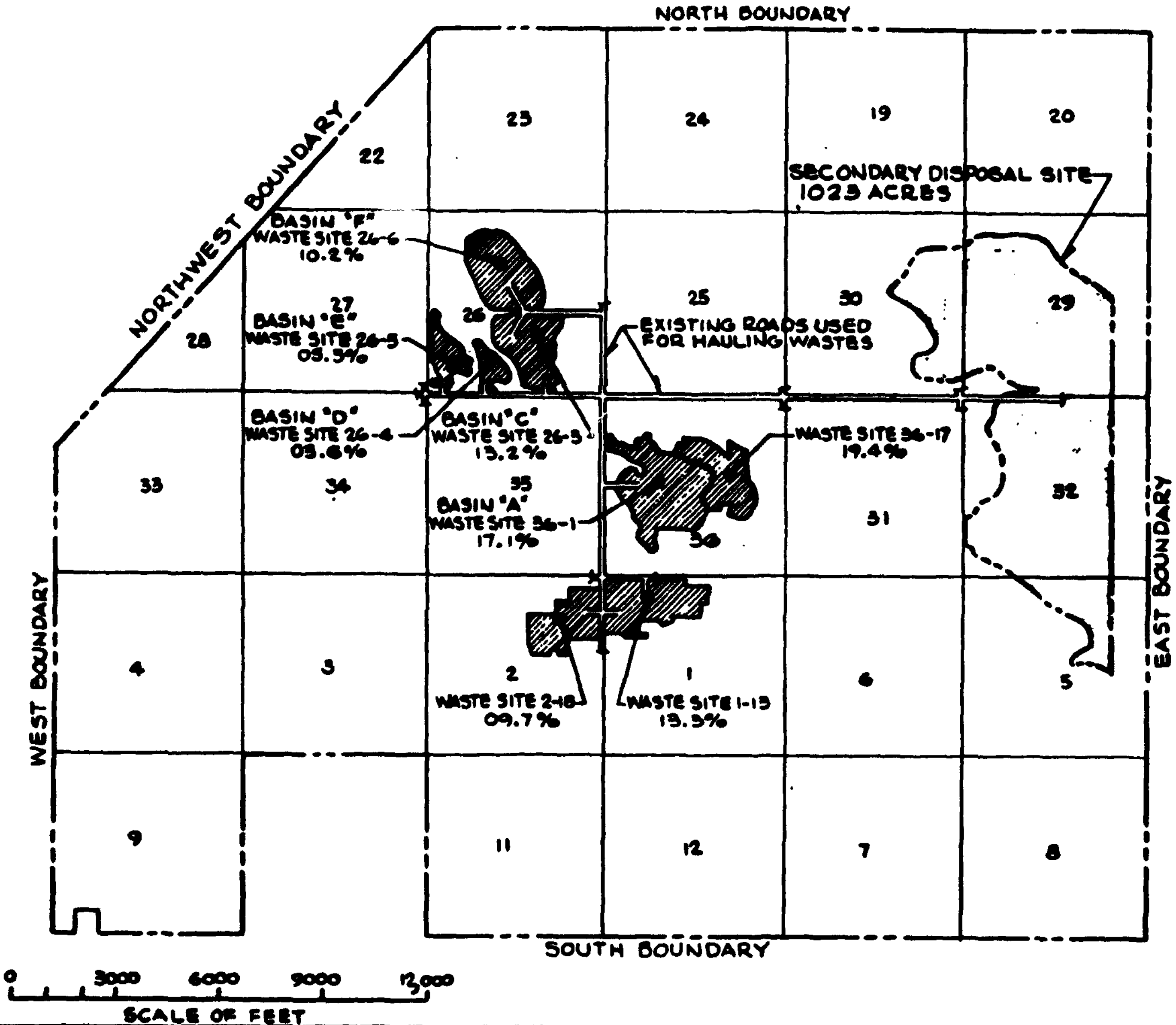
Particular attention should be paid to the preferential development of the portion of the secondary site (Site 6B), which has a 40 foot depth to groundwater. The demonstration of protective life of the waste cells having a 40 foot depth to groundwater is facilitated by locating the cells in areas having the maximum depth to groundwater. Figure 6-9 shows a facility for 1,000,000 or 1,500,000 cy cells, which primarily occupies that portion of the site.

The arrangements shown in the figures should be regarded as flexible for pattern and cell size selection. It should also be understood that these are not the only possible facility plans that fit the sites. Given the general nature of the information used to establish site



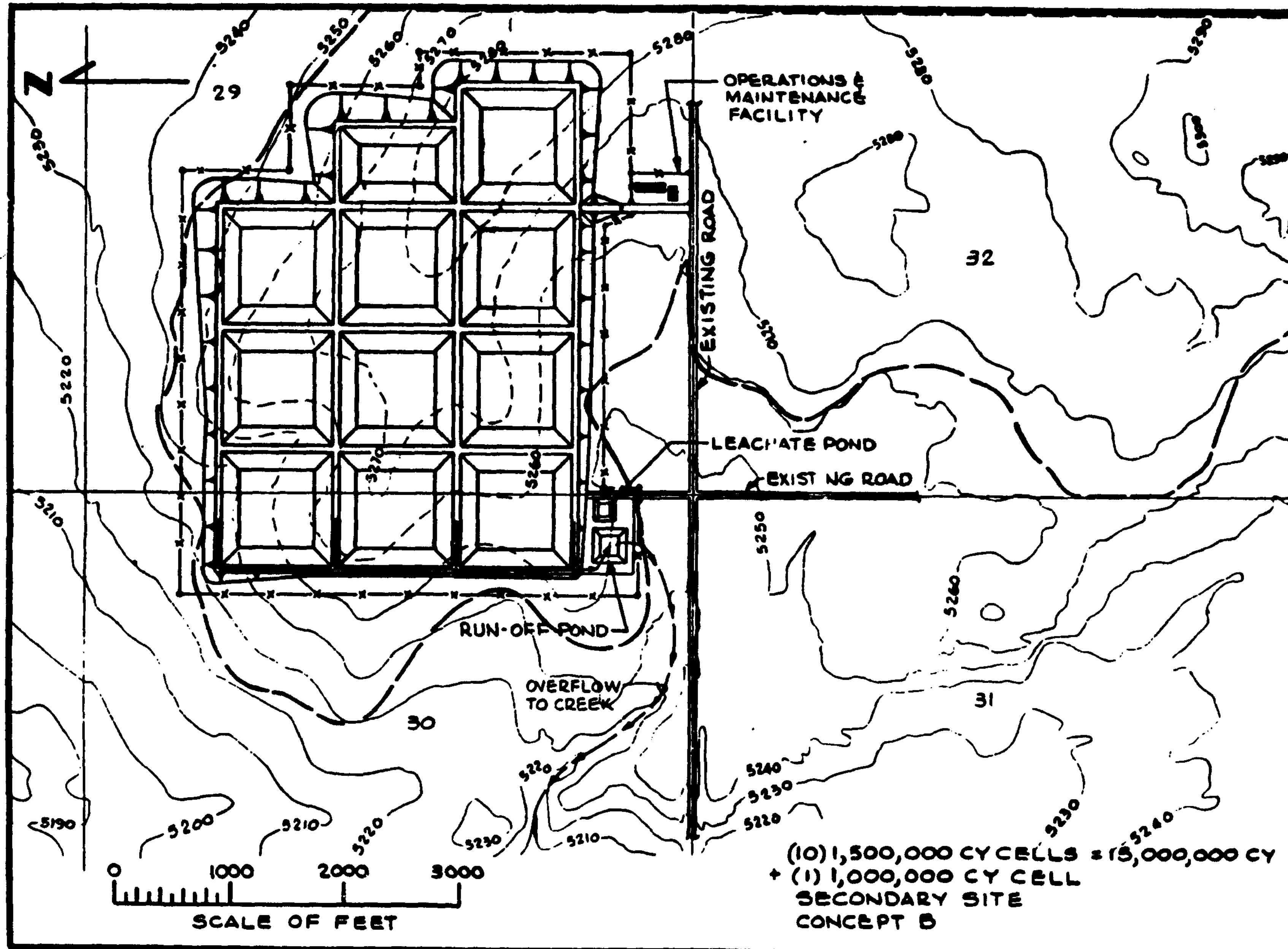
(64) 250,000 CY CELLS = 16,000,000 CY
SECONDARY SITE
CONCEPT D

EBASCO	RMA TASK 27 FIGURE 6-8



SECONDARY DISPOSAL SITE
90% OF RMA WASTE LIST
REFERENCE TABLE :
13.3% - WASTE SITE 1-13
09.7% - WASTE SITE 2-18
13.2% - WASTE SITE 26-3
05.6% - WASTE SITE 26-4
05.3% - WASTE SITE 26-5
10.2% - WASTE SITE 26-6
17.1% - WASTE SITE 36-1
19.4% - WASTE SITE 36-17

EBASCO
RMA TASK 27
FIGURE 6-7



EBASCO

RMA TASK 27

FIGURE 6-9

7.0 COST ESTIMATE SUMMARY AND ECONOMIC COMPARISON

7.1 GENERAL

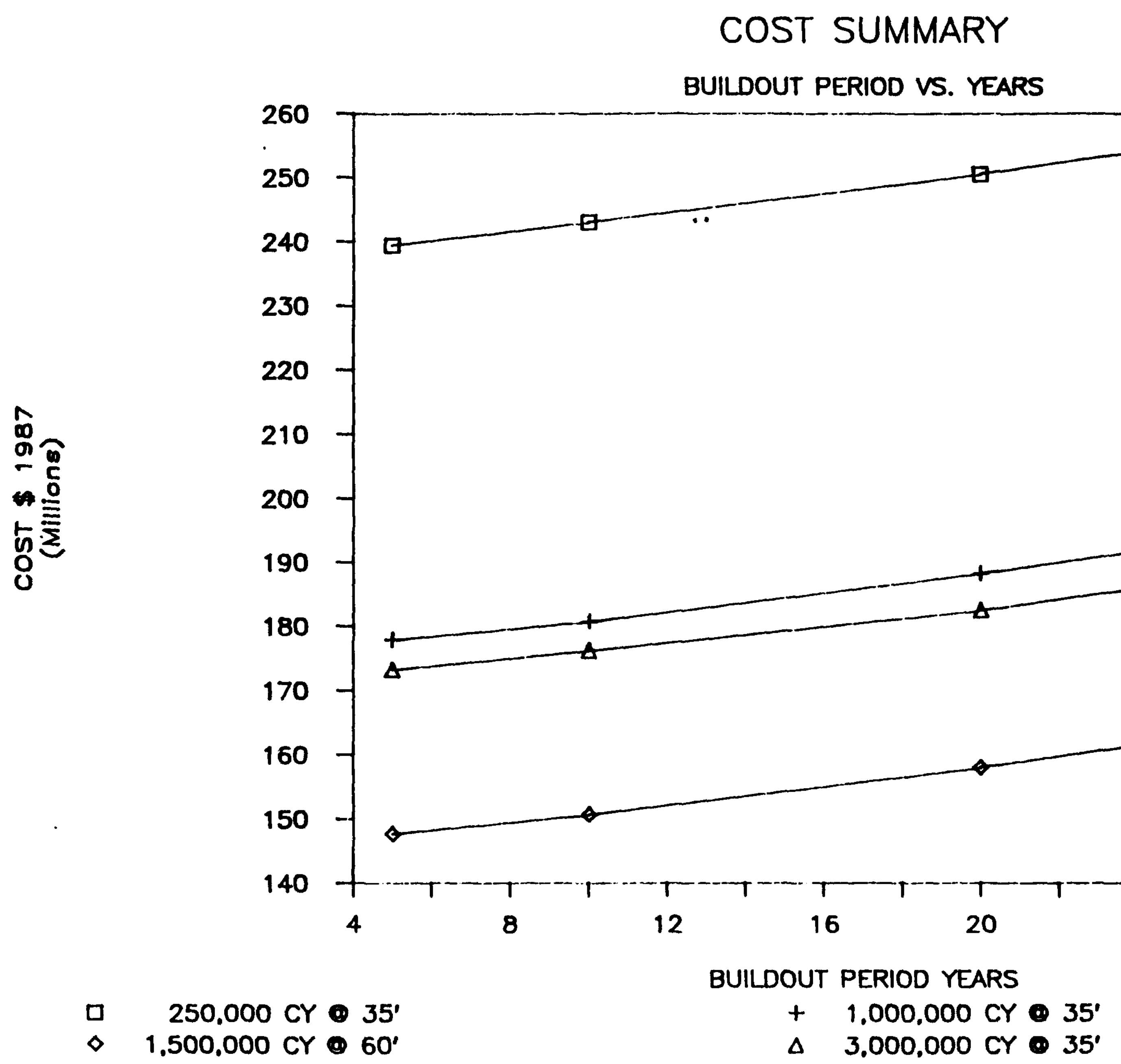
A cost analysis was prepared for the land disposal facility to evaluate effects of varying the buildout time period and cell volume or size. The results of the estimate are summarized in a graph (Figure 7-1) that depicts total cost in 1987 dollars against buildout period and cell size. Costs are also presented as present worth in 1987 dollars based on a 4 percent annual discount rate (Figure 7-2). The discount rate is the difference between inflation and interest rates and therefore represents the net saving achieved by deferring construction expenses to a future date. The present worth costs allow for a direct comparison among alternative buildout schedules. The graphs are intended for use as a management tool to help select an appropriate cell size and buildout period.

Cost estimates were evaluated for four buildout periods: 5, 10, 20, and 30 years. Each buildout period was then evaluated for four cell sizes: 250,000; 1,000,000; 1,500,000; and 3,000,000 cy, for a total of 16 estimates. The detailed cost estimates can be found in Appendix IV.

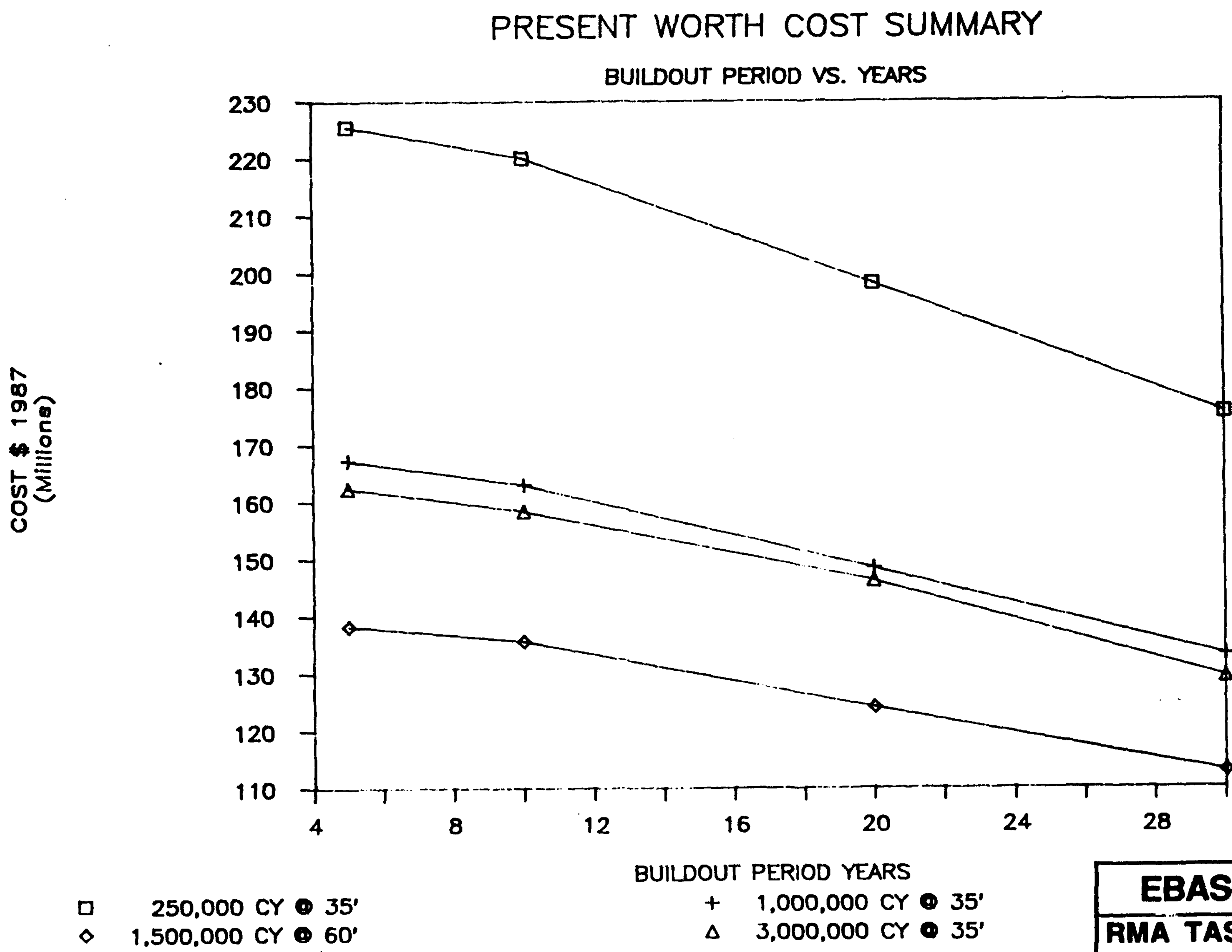
Each cost estimate in Appendix IV is divided into four tables: 1) construction, 2) operation and maintenance, 3) closure, 4) and post-closure.

7.2 ASSUMPTIONS

The assumptions made within the study that influence the estimated cost of the facility include: 1) all treated or untreated hazardous waste materials, 16,000,000 cy, will be disposed in the on-site land disposal facility; 2) construction periods of 5, 10, 20, and 30 years; 3) a post-closure period of 30 years beyond completion of the facility 4) lump sum end-of-year payments for computing the present worth of costs; and 5) a 4 percent discount rate for present worth calculations.



EBASCO
RMA TASK 27
FIGURE 7-1



EBASCO
RMA TASK 27
FIGURE 7-2

7.3 ESTIMATED COSTS

7.3.1 Construction

Construction costs are assumed to be all costs associated with placement of the first cubic yard of material in a cell. This includes costs of site preparation, support buildings, roads, surface water control, monitoring wells, fencing, and cell construction. In addition, a 10 percent fee for engineering design and a 15 percent contingency fee for unforeseen price increases were included.

The construction costs do not include berm construction costs or placement of waste material in the cell. The unit cell costs are ir-luded as line items in Table 1 of the cost estimates provided in A, -endix IV.

7.3.2 Operation and Maintenance

Operation costs are composed primarily of waste transportation and administrative personnel costs. Waste transportation costs were estimated in two parts: haul costs and load/unload costs. Haul costs are considered to be costs associated with the transportation of wastes from the contamination site to the land disposal facility. Haul costs depend on haul distances and thus vary from one contamination site to another.

Load/unload costs are considered to be costs associated with the placement and removal of material from haul trucks. Since waste placement rates are kept uniform over the buildout period, load/unload costs are likewise uniform. The waste transportation costs for each buildout period are included in Appendix IV.

Administrative personnel costs are overhead costs not reflected in construction and operation and maintenance cost estimates. Administrative personnel include a site manager, foremen, laborers,

quality assurance/control inspectors, health and safety inspectors, field engineers, technicians, security people, and secretaries. The required number of administrative personnel depends on waste placement rates and hence varies with the buildout period.

Maintenance costs are associated with haul and access roads, the surface water control system, and buildings. Maintenance costs are a relatively small percentage of the operation costs.

Costs of any required waste treatment prior to disposal are not included, nor are rehandling costs, transportation to or from treatment facility, or residue testing. Also, costs of demolition of contaminated buildings are not included, only the costs associated with loading and transporting the building rubble.

7.3.3 Closure

The closure period for the purpose of the cost estimates is defined as the period following completion of the waste cells and associated construction up to the time that post-closure activities begin. Activity during the closure period includes final decontamination of roads and equipment, removal of temporary structures, and general demobilization of construction forces and equipment. Closure costs will be incurred during the last year of the buildout period. Closure costs are shown in Table 2 of the cost estimates provided in Appendix IV.

7.3.4 Postclosure

The post-closure period has been assumed to be the 30 years immediately following the completion of construction and closure activities. Costs during this period are associated with three ongoing activities that include: monitoring, sampling, and testing; site security; and facility inspection and maintenance. Costs for these activities are shown in Table 3 of the cost estimates provided in Appendix IV.

7.4 ECONOMIC ANALYSIS

The economic analysis provides a comparison of the costs associated with various buildout periods, cell sizes, and depth of waste placed within the cells. Figure 7-1 shows the total buildout costs for a given cell size over a range of buildout periods. Figure 7-1 is based on the total buildout cost in 1987 dollars and does not take into consideration the time value of money. The present worth of construction cost in 1987 dollars is shown in Figure 7-2. The present worth analysis was based on a 4 percent discount rate which is considered reasonable based on present economic conditions.

It can be seen that the total facility cost is sensitive to cell size. The 250,000 cy cell facility is 30 to 50 percent more expensive than the larger sizes examined. Of the cell sizes examined, the 3,000,000 or 1,500,000 cy cell facilities are the most economical.

All the facility alternatives examined, however, are much more economical than the previous concept design for Basin F wastes (IT Corporation 1984). That facility was estimated to cost $27,265,000 for disposal of 600,000 cy, or $45.44 per cy. If scaled up at the same unit cost, disposal of 16,000,000 cy of waste would cost $727,000,000, in 1984 dollars. This is nearly three times as much as the most expensive alternative developed in this task and five times as much as the least expensive. The difference between the cost of the previous concept design and those developed in this task is principally attributed to the small cell size (100,000 cy) used in that design in order to fit into a temporary building. It was concluded in this task that covered construction was not required at RMA and therefore more economical cell sizes could be examined.

The detailed printouts of the cost estimates in Appendix IV provide the basis for calculating costs for a wide range of possible facility schemes. Sufficient unit cost detail is displayed to readily calculate the cost of smaller or larger capacity facilities, or by interpolation,

facilities with cell sizes or buildout periods different from those developed in this task.

The accuracy of the estimates is appropriate to feasibility study use, for example technology comparison and selection, not for budgeting purposes. An allowance was made for design engineering costs and a 15 percent construction costs contingency; however, other indirect costs and owner's expenses are not included.

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13. ABSTRACT *(Maximum 200 words)*

THE PURPOSE OF TASK 27 IS TO PERFORM AN ASSESSMENT OF A LAND DISPOSAL FACILITY CAPABLE OF CONTAINING ALL RMA WASTE. THIS REPORT COVERS SITE SELECTION, DESIGN CRITERIA, AND CONCEPT ASSESSMENT. THE REPORT IS DIVIDED INTO THE FOLLOWING SECTIONS:

1. SUMMARY
2. INTRODUCTION
3. SITE SELECTION - ASSUMPTIONS, METHODS, RESULTS, RECOMMENDATIONS
4. DESIGN OBJECTIVES AND CRITERIA
5. WASTE CELL CONCEPTS - MATERIAL, COMPONENTS, CONSTRUCTION
6. FACILITY CONFIGURATION
7. COST ESTIMATE SUMMARY AND ECONOMIC COMPARISON.

APPENDICES INCLUDE:

1. WASTE CHARACTERIZATION
2. LAND DISPOSAL CONCEPTS

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